



Otto-Friedrich Universität Bamberg

Module Handbook

Master's Degree Programme International Software Systems Science

Faculty of Information Systems and Applied Computer Sciences

According to the valid version of the study and examination regulations of 06.03.2015 for the Master's degree programme International Software Systems Science at of the Otto Friedrich University of Bamberg. Valid from winter semester 2020/21.

Notice on the validity of older versions of a module handbook:

1. date of validity

The module descriptions contained in this module handbook are valid for the first time for the semester indicated on the cover sheet.

2. transition regulations

a. Students who have already completed parts of a module according to the previously valid module handbook (cf. no. 2b) shall complete the module according to the previously valid version of the module handbook.

This transition regulation shall apply exclusively to the regular examination date immediately following the missed/not passed/not completed examination. At the request of the student, the examination board may, in justified cases, determine an extension of the transition period.

b. A module shall be deemed to have been completed in parts if the module examination has not been passed or missed. The same shall apply if at least one module examination has been passed, failed or missed.

Furthermore, a module shall be deemed to have been *partly completed* if the student has registered for a course assigned to the respective module in accordance with the previously applicable module handbook.

3. period of validity

This module handbook is valid for subsequent semesters *until the announcement of a changed module handbook*.

**Equivalence List M.Sc. International Software Systems Science,
Examination Regulations of 06.03.2015**

In the following you will find a list of modules whose name or abbreviation has been changed without a significant change to the module. If a module listed in the column "previous module" was successfully completed, the module listed in the column "new module" cannot be taken.

previous module			new module		
module abbreviation	module name	valid until (semester)	module abbreviation	module name	valid from (semester)
MOBI-DSC	Data Streams and Complex Event Processing	SS 18	MOBI-DSC-M	Data Streams and Complex Event Processing	WS 1819

Additional information on the attribution of study focus fields for seminar modules:

seminar module	possible study focus	
DSG-Sem-M	S1 Distributed and Mobile Systems	S3: Service-oriented Architectures
Gdl-Sem-M	S2: Software Analysis and Verification	
KTR-Sem-M	S4: Communication Systems and Protocols	
MOBI-SEM-M	S1: Distributed and Mobile Systems	
PSI-Sem-M	S1: Distributed and Mobile Systems	S4: Communication Systems and Protocols
SWT-SEM-M	S2: Software Analysis and Verification	

Seminars in Applied Computer Science are not attributable to a study focus in this course of studies.

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DSG-SOA-M: Service-Oriented Architecture and Web Services.....	16
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Gdl-CSNL-M: Computational Semantics of Natural Language.....	32
Gdl-FP-M: Functional Programming.....	34
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HCI-Sem-M: Master-Seminar Human-Computer Interaction.....	45
HCI-US-B: Ubiquitous Systems.....	47
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KTR-Sem-M: Master Seminar Communication Systems and Computer Networks.....	65
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1) Software Systems Science for students starting before WS 19/20 (Modulgruppe) ECTS: 30 - 48

In module groups A1 and A2, modules totalling 48 ECTS points are to be completed in accordance with the minimum and maximum limits applicable to the module groups.

DSG-DSAM-M: Distributed Systems Architectures and Middleware (6 ECTS, every winter semester).....	9
DSG-DistrSys-M: Distributed Systems (6 ECTS, every summer semester).....	11
DSG-SOA-M: Service-Oriented Architecture and Web Services (6 ECTS, every summer semester).....	16
DSG-SRDS-M: Selected Readings in Distributed Systems (3 ECTS, every semester).....	19
GdI-AFP-M: Advanced Functional Programming (6 ECTS, every summer semester).....	29
GdI-FP-M: Functional Programming (6 ECTS, every winter semester).....	34
KTR-GIK-M: Foundations of Internet Communication (6 ECTS, every summer semester).....	50
KTR-MAKV-M: Modeling and Analysis of Communication Networks and Distributed Systems (6 ECTS, every summer semester).....	53
KTR-MMK-M: Multimedia Communication in High Speed Networks (6 ECTS, every summer semester).....	56
KTR-Mobi-M: Mobile Communication (6 ECTS, every winter semester).....	59
MOBI-ADM-M: Advanced Data Management (6 ECTS, every summer semester).....	71
MOBI-DSC-M: Data Streams and Complex Event Processing (6 ECTS, every winter semester).....	73
PSI-AdvaSP-M: Advanced Security and Privacy (6 ECTS, every summer semester).....	78
SWT-ASV-M: Applied Software Verification (6 ECTS, every summer semester).....	95
SWT-CPS-M: Cyber-Physical Systems (6 ECTS, every winter semester).....	97
SWT-PCC-M: Principles of Compiler Construction (6 ECTS, every summer semester).....	100

2) A1 Software Systems Science for students starting from WS 1920 onwards (Modulgruppe) ECTS: 30 - 48

In module groups A1 and A2, modules totalling 48 ECTS credits must be completed in accordance with the minimum and maximum limits applicable to the module groups.

a) elective modules (Teilmodulgruppe) ECTS: 0 - 18

DSG-DistrSys-M: Distributed Systems (6 ECTS, every summer semester).....	11
DSG-SOA-M: Service-Oriented Architecture and Web Services (6 ECTS, every summer semester).....	16
DSG-SRDS-M: Selected Readings in Distributed Systems (3 ECTS, every semester).....	19

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Gdl-FP-M: Functional Programming (6 ECTS, every winter semester).....	34
KTR-MAKV-M: Modeling and Analysis of Communication Networks and Distributed Systems (6 ECTS, every summer semester).....	53
KTR-MMK-M: Multimedia Communication in High Speed Networks (6 ECTS, every summer semester).....	56
KTR-Mobi-M: Mobile Communication (6 ECTS, every winter semester).....	59
MOBI-ADM-M: Advanced Data Management (6 ECTS, every summer semester).....	71
SWT-ASV-M: Applied Software Verification (6 ECTS, every summer semester).....	95
SWT-CPS-M: Cyber-Physical Systems (6 ECTS, every winter semester).....	97

b) compulsory part (Teilmodulgruppe) ECTS: 30

DSG-DSAM-M: Distributed Systems Architectures and Middleware (6 ECTS, every winter semester).....	9
KTR-GIK-M: Foundations of Internet Communication (6 ECTS, every summer semester).....	50
MOBI-DSC-M: Data Streams and Complex Event Processing (6 ECTS, every winter semester).....	73
PSI-AdvaSP-M: Advanced Security and Privacy (6 ECTS, every summer semester).....	78
SWT-PCC-M: Principles of Compiler Construction (6 ECTS, every summer semester).....	100

3) A2 Domain-specific Software Systems Science (Modulgruppe) ECTS: 0 - 18

In module groups A1 and A2, modules totalling 48 ECTS points are to be completed in accordance with the minimum and maximum limits applicable to the module groups.

EESYS-DAE-M: Data Analytics in Energy Informatics (6 ECTS, every winter semester).....	23
EESYS-ES-M: Energy Efficient Systems (6 ECTS, every summer semester).....	26
Gdl-CSNL-M: Computational Semantics of Natural Language (6 ECTS, every summer semester).....	32
HCI-MCI-M: Human-Computer Interaction (6 ECTS, every summer semester).....	38
HCI-US-B: Ubiquitous Systems (6 ECTS, every winter semester).....	47
KogSys-ML-M: Machine Learning (6 ECTS, every winter semester).....	67
SME-STE-M: Introduction to Knowledge Representation: Space, Time, Events (6 ECTS, every winter semester).....	88
SNA-OSN-M: Project Online Social Networks (6 ECTS, every winter semester).....	90

4) A3 Seminar and Project (Modulgruppe) ECTS: 12

a) Elective Unit A3WP1: Seminar (Teilmodulgruppe) ECTS: 3

DSG-Sem-M: Master Seminar in Distributed Systems (3 ECTS, every semester).....	21
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Gdl-Sem-M: Master's Seminar Theoretical Computer Science (3 ECTS, winter or summer semester, on demand).....	36
HCI-Prop-M: Propaedeutic: Human-Computer-Interaction (3 ECTS, every winter semester).....	41
HCI-Sem-HCC-M: Master-Seminar Human-Centred Computing (3 ECTS, every summer semester).....	43
HCI-Sem-M: Master-Seminar Human-Computer Interaction (3 ECTS, every winter semester).....	45
KTR-Sem-M: Master Seminar Communication Systems and Computer Networks (3 ECTS, winter or summer semester, on demand).....	65
KogSys-Sem-M2: Reading Club Cognitive Systems (3 ECTS, every summer semester).....	69
MOBI-SEM-M: Master-Seminar Mobile Software Systems (3 ECTS, every winter semester).....	77
PSI-Sem-M: Seminar Research Topics in Security and Privacy (3 ECTS, every winter semester).....	86
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MOBI-PRS-M: Master Project Mobile Software Systems (SoSySc) (9 ECTS, every summer semester).....	75
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5) A4: Masters Thesis (Modulgruppe) ECTS: 30

SSS-Thesis-M: Master's Thesis in Software Systems Science (30 ECTS, every semester).....	93
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6) A5 International Experience (Modulgruppe) ECTS: 30

According to the examination regulations (StuFPO) Appendix 1, students have four options regarding the Module Group A5, *International Experience*, which may also be combined:

- (1) to study modules of software systems science at a university abroad for at least one semester or
- (2) to accomplish a traineeship in an international context, preferentially abroad, that covers topics of the occupational field of software systems science with a volume of at least 360 working hours (12 ECTS credits).
- (3) to accomplish *further* modules of module groups A1 and A2 (Examination Regulations, App. 1)
- (4) to accomplish up to 18 ECTS credits in modules of foreign languages (neither English nor native language).

a) Guided graduate study abroad (Teilmodulgruppe) ECTS: 0 - 30

Regarding the study of software systems science modules at a university abroad, courses with a workload equivalent to 30 ECTS credits can be accomplished.

The courses that are selected at a foreign university have to be approved by learning agreements. For own planning security reasons, learning agreements have to be signed by those Professors at University of Bamberg responsible for the chosen subject, as well as the head of the Examination Board, before the graduate study abroad is initiated.

b) Internship in an International context (Teilmodulgruppe) ECTS: 0 - 12

Regarding the elective area 5b, *Internship in an international context*, with an equivalent workload of 12 ECTS credits, a foreign or internationally acting domestic company (or research institute) may be selected.

It has to offer a specific internship related to relevant topics of software systems science. The documentation of the internship requires the delivery of the following items to the degree programme representative:

- written report of 4 pages at least, reporting on the tasks and achievements, and
- a certificate issued by the hosting institution or the organizational unit that has realized the internship.

SSS-PraktIntKon-M: Internship in an International Context (12 ECTS, every semester)..... 92

c) Foreign languages (Teilmodulgruppe) ECTS: 0 - 18

In the elective area 5c, *Foreign languages*, modules comprising up to 18 ECTS credits can be taken from the range offered by the University's Language Centre. Excluded are modules of the English language and modules of the language in which the university entrance qualification was obtained.

Details, in particular the modules available for selection and the respective Module examinations are described (in German) in the *Modulhandbuch des Sprachenzentrums der Otto-Friedrich-Universität Bamberg*.

d) further modules from module groups A1 and/ or A2 (Module Group) ECTS: 0 - 30

Additional, not previously completed modules from A1 or A2 module groups' required elective options in accordance with the Examination Regulations, Appendix 1.

Module DSG-DSAM-M Distributed Systems Architectures and Middleware		6 ECTS / 180 h 45 h Präsenzzeit 135 h Selbststudium
<i>Distributed Systems Architecture and Middleware</i>		
(since WS19/20)		
Person responsible for module: Prof. Dr. Guido Wirtz		
Contents:		
<p>This course introduces students to the ideas, benefits, technologies and issues related to server-centric distributed systems and middleware in general. The core topics are centered around component technologies such as Java EJBs, Business-to-Business technologies like EDI and ebXML, and Cloud Computing facilities like Google App Engine and Windows Azure. Thus the course introduces and discusses in-depth topics concerning distributed middleware and its practical use:</p> <ul style="list-style-type: none"> • Characteristics and Foundations of Distributed Systems • Classical Middleware and Services • Concurrency and Synchronization • Component Technologies • Cloud Computing, in particular platform as a service • Business-to-Business Technologies <p>The selection of topics and teaching method of this course reflects the Distributed Systems Group's (DSG) dedication to integrate business and IT, theory and practice, research and teaching. You not only will be taught the classical way, but you will have hands-on experience on middleware development and middleware tools. Also, you will get the chance to discuss selected publications with your lecturers.</p>		
Learning outcomes:		
Students are able to evaluate, plan, design and implement server-centric distributed systems. Students are familiar with recent approaches and standards for building and managing such systems, know about the central problems involved as well as ways to overcome these issues. Students have hands-on experience with up-to-date middleware and tools for building server-centric systems.		
Remark:		
The main language of instruction in this course is English.		
prerequisites for the module:		
Basic knowledge in software engineering and in distributed systems as introduced, e.g., in the module DSG-IDistrSys-B (or DSG-DistrSys-M).		
Recommended prior knowledge:		Admission requirements:
Basic knowledge in software engineering and in distributed systems as introduced, e.g., in the module DSG-IDistrSys.		none
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module: 1 Semester
Module Units		
1. Lectures Distributed Systems Architecture and Middleware		2,00 Weekly Contact Hours
Mode of Delivery: Lectures		
Lecturers: Prof. Dr. Guido Wirtz		
Language: English		
Frequency: every winter semester		

<p>Learning outcome: c.f. overall module description</p> <hr/> <p>Contents: c.f. overall module description</p> <hr/> <p>Literature: This is a fast emerging field with new insights every year. So, up-to-date literature will be provided at the beginning of each course.</p>	
<p>2. Practicals Distributed Systems Architecture and Middleware Mode of Delivery: Practicals Lecturers: Scientific Staff Praktische Informatik Language: English/German Frequency: every winter semester</p> <hr/> <p>Learning outcome: c.f. overall module description</p> <hr/> <p>Contents: Introduction to and discussion of tools and practical issues closely related to the topics discussed in the lecture as well as solutions of problems that come up during working on the practical assignment.</p> <hr/> <p>Literature: c.f. overall module description</p>	<p>2,00 Weekly Contact Hours</p>
<p>Examination Coursework Assignment and Colloquium / Duration of Examination: 15 minutes Duration of Coursework: 3 months</p> <p>Description: Oral examination concerning the topics discussed in the lecture, exercises and assignment. Students may choose English or German as the language for the oral examination. Examinations will take place at the end of the winter term or at the begin of the summer term (students may choose one of them). Students are assumed to work on a programming assignment ('schriftliche Hausarbeit') during the semester that is introduced at the beginning of the semester and uses the most important technologies discussed during the semester.</p> <p>Note: Without working on the programming assignment over the term students may run into problems during their oral examination (Kolloquium) as we discuss questions concerning topics from the lectures as well as from the assignment; questions about the assignment are based on the assignment solution programmed by the students.</p>	

Module DSG-DistrSys-M Distributed Systems <i>Distributed Systems</i>	6 ECTS / 180 h 45 h Präsenzzeit 135 h Selbststudium
(since SS20) Person responsible for module: Prof. Dr. Guido Wirtz	
Contents: Nowadays infrastructure and business relies more or less on distributed systems of various flavors. Most of our civilization would not work any more if all distributed systems would fail. So, that should be a good reason for anyone planning to work in the context of IT to learn at least about the characteristics and basic issues of such systems. The course introduces to the different flavors of and issues with distributed systems, discusses the most basic problems arising with this kind of systems and presents solutions and techniques that are essential to make distributed systems work. Additionally, the course also teaches how to build simple distributed systems using Java-based technologies like process interaction, synchronization, remote message invocation and web service infrastructure. Students are required to work (in groups) on assignments in order to combine the theoretical concepts with practical experience and ... Yes, we program!	
Learning outcomes: Students know about the characteristics and different flavors of distributed systems and understand the essential differences compared to monolithic, centralized systems as well as their consequences when designing and building distributed systems. Students are able to apply the basic algorithmic techniques and programming paradigms in order to build simple distributed systems themselves. Students have gained basic experience with practically building and running distributed systems.	
Remark: The language of instruction in this course is English. The overall workload of 180h for this module consists of: <ul style="list-style-type: none"> • weekly classes: 22.5h • tutorials: 22.5h • Work on assignment: 75h • Literature study 30h • preparation for and time of the final exam: 30h This course is intended for 2nd/3rd year bachelor students as well as master students which have not enrolled in a similar course during their bachelor studies. In case of questions don't hesitate to contact the person responsible for this module.	
prerequisites for the module: none	
Recommended prior knowledge: Knowledge of the basics of computer science in general, esp. operating systems, as well as practical experience in Java programming, as the subjects taught in DSG-EiAPS-B and DSG-EiRBS-B. Preferable also knowledge about multithreading and synchronization like, e.g., the subject-matters of DSG-PKS-B. Module Introduction to Parallel and Distributed Programming (DSG-PKS-B) - recommended	Admission requirements: none

Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester
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Module Units	
<p>1. Lecture Distributed Systems Mode of Delivery: Lectures Lecturers: Prof. Dr. Guido Wirtz Language: English/German Frequency: every summer semester</p> <hr/> <p>Learning outcome: c.f. module description</p> <hr/> <p>Contents: c.f. module description</p> <hr/> <p>Literature:</p> <ul style="list-style-type: none"> • George Coulouris, Jean Dollimore, Tim Kindberg, Gordon Blair: Distributed Systems - Concepts and Design. Pearson Education UK, 2011 (5. edition); • Andrew Tanenbaum, Marten van Steen: Distributed Systems - Principles and Paradigms, 2017 (3rd edition) • Additional research literature will be provided during the term for selected readings and discussions 	2,00 Weekly Contact Hours
<p>2. Tutorial Distributed Systems Mode of Delivery: Practicals Lecturers: Scientific Staff Praktische Informatik Language: German Frequency: every summer semester</p> <hr/> <p>Learning outcome: c.f. module description</p> <hr/> <p>Contents: Introduction to and discussion of tools and practical issues closely related to the topics discussed in the lecture as well as solutions of problems that come up during working on the practical assignment.</p>	2,00 Weekly Contact Hours

<p>Examination Coursework Assignment and Colloquium / Duration of Examination: 15 minutes Duration of Coursework: 3 months</p> <p>Description: Oral examination concerning the topics discussed in the lecture, exercises and assignment. Students may choose English or German as the language for the oral examination. Examinations will take place at the end of the summer term or at the begin of the winter term (students may choose one of them).</p> <p>Students are assumed to work on a programming assignment ('schriftliche Hausarbeit') during the semester that is introduced at the beginning of the semester and uses the most important technologies discussed during the semester.</p>	
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Note: Without working on the programming assignment over the term students may run into problems during their oral examination (Kolloquium) as we discuss questions concerning topics from the lectures as well as from the assignment; questions about the assignment are based on the assignment solution programmed by the students.

Module DSG-Project-M Master Project Distributed Systems		9 ECTS / 270 h
<i>Masterproject Distributed Systems</i>		
(since SS19)		
Person responsible for module: Prof. Dr. Guido Wirtz		
Contents:		
<p>Within the project, a comprehensive topic in the field of system development in group work. Students work on problems that also arise in practice, with the most independent solution possible of a larger one, only conditionally solvable task in partly concretely given basic conditions. The Master-Project differs from the project work in the Bachelor's programme in the complexity of the task and the direct relation to current scientific work of the chair.</p>		
Learning outcomes:		
<p>Ability to independently develop solutions to problems on the basis of the acquired knowledge and the acquired skills from their studies as well as current scientific literature; ability to solve complex problems within the framework of a systematic engineering development process into software and to document it professionally; ability to teamwork; scientific curiosity and the formation of a self-confident and researching Attitude towards technology.</p>		
Remark:		
<p>Compilation of a written project report, a poster on the project result and the existence of the verbal attestation of the project result.</p> <p>The workload of 270 hours in total (as a block according to the respective SoSe) is roughly divided into</p> <ul style="list-style-type: none"> - 35 hrs. introduction, presentation of tools, short lectures - 30 hours of research on and familiarization with the topic of the project including preparation of Short presentations - 180 hours practical project work (software development) - 15 hours of writing the project report and creating the joint poster - 10 hours of preparation for the certificate (under the above-mentioned expenses already incurred) 		
prerequisites for the module:		
none		
Recommended prior knowledge:		Admission requirements:
<p>The module builds on the DSG-DistrSys-M or DSG-IDistrSys-B (Introduction to) Distributed Systems module. Depending on the topic, also the previous visit to one of the events DSG-SOA-M or DSG-DSAM-M (to be announced at Theme announcement).</p> <p>Students of the subject are expected to master a higher (object-oriented) programming language and the Readiness for practical work on the computer expected.</p> <p>Modules Introduction to Distributed Systems (DSG-DistrSys-B)</p> <p>Module Einführung in Verteilte Systeme (DSG-EiDistrSys) -</p>		none
Frequency: every semester	Recommended semester:	Minimal Duration of the Module:
		1 Semester

Module Units	
<p>Distributed Systems Project Mode of Delivery: Practicals Lecturers: Prof. Dr. Guido Wirtz, Scientific Staff Praktische Informatik Language: English Frequency: every semester</p> <hr/> <p>Learning outcome: see module description</p> <hr/> <p>Contents: Building on the knowledge gained in the lectures and exercises in the Distributed systems is presented in this event and the knowledge and skills acquired implemented a smaller project with scientific reference in a group After a short introduction to the technologies used and tools will be developed in a project with different working groups/packages organized form a related problem from the field of distributed and mobile systems. Usually this involves a prototype of a complex distributed software system or tool consisting of in this area.</p> <hr/> <p>Literature: depends on the project topic</p>	6,00 Weekly Contact Hours
<p>Examination Coursework Assignment and Colloquium / Duration of Examination: 10 minutes Duration of Coursework: 3 months prerequisites for module examination: regular participation in the course and working in groups on the assignments Description: Report on the own contribution made to the project as clearly identified Part of the general report of the project group; collaboration in the preparation of a Poster demonstration of the project results. Oral examination discussion about the contents of the project, in particular the conceptual and practical work done by the respective student Services.</p>	

Module DSG-SOA-M Service-Oriented Architecture and Web Services <i>Service-Oriented Architecture and Web Services</i>	6 ECTS / 180 h 45 h Präsenzzeit 135 h Selbststudium
(since SS20) Person responsible for module: Prof. Dr. Guido Wirtz	
<p>Contents:</p> <p>Building enterprise-scale IT systems requires sound concepts for integrating software. Service-oriented architectures (SOAs) have been the number one answer to this integration challenge for years. Indeed, service orientation is and will be a cornerstone in modularizing large IT landscapes and alignment with business needs is the driving factor for service engineering. A SOA composes an IT system from services in a loosely-coupled manner. Each service implements a business task and therefore have a clear value attribution. When business needs change, the loose coupling of services allows for quick adjustment of the SOA. In recent years, Microservices have been put forward as a new paradigm for organizing software-intensive systems as a set of small services that communicate using lightweight communication technologies and are <i>independently deployable by fully automated deployment machinery</i>. Conceptually, Microservices and SOA share a lot, but the Microservices paradigm puts a lot more emphasis on automation in development and therefore is a better fit for modern development practices.</p> <p>When moving beyond company boundaries and opening up the solution space is necessary, software ecosystems (SECOs) come into play. Software ecosystems integrate software contributions from independent organizational entities and enable software products and solutions that a single company cannot realize alone. Prominent representatives of software ecosystems are Android and the Playstore or iOS and the AppStore. But the paradigm of software ecosystems goes far beyond mobile platforms and also covers application areas in the cloud domain or the embedded domain.</p> <p>Skilled software architects therefore reconcile the business views and technical views for the benefit of the enterprise and therefore need both, advanced knowledge in business process and workflow management as well as a rock-solid understanding of service engineering and distributed computing.</p> <p>This course will introduce you to the world of architectures for large-scale software by giving a brief overview on distributed systems and software architecture in general. Then SOAs as an architectural paradigm and Web Services (WSDL + REST) as SOA implementation technology will be treated in detail. SOA will be contrasted to Microservices and the development aspects that Microservices focuses on will be discussed. Software ecosystems then will be introduced as a paradigm for organizing software systems and container technology (Linux Containers (LXC) and Docker) as a frequent implementation means for software ecosystems will be introduced. In particular, we will investigate what building industry-grade ecosystems based on container technology means in practice.</p> <ul style="list-style-type: none"> • Conceptual Foundations of SOA • SOA Characteristics • Microservices • WSDL and Basic Web Services • REST-ful Services • Software Ecosystems • Container technology <p>The selection of topics and teaching method of this course reflects the Distributed Systems Group's (DSG) dedication to integrate business and IT, theory and practice, research and teaching. You not only will be taught the classical way, but you will have hands-on experience on service development and SOA tools.</p>	

Also, you will get a grasp of current services research and you will get the chance to discuss selected publications with your lecturers.

Learning outcomes:

Students know about the different aspects of service-oriented architectures and their practical use.

Students

- Understand the characteristics of SOAs, Microservices and SECOs and its implications on IT systems.
- Know relevant technologies and standards in the field and being able to combine some of these to develop basic Web Services and service compositions
- Being able to compare WSDL Web Services to REST Web Services
- Being able to use container technology for integrating software
- Being able to judge IT architectures from a SOA/Microservices/SECO perspective.
- Being able to understand and discuss scientific work in the area

Remark:

The main language of instruction in this course is English.

The overall workload of 180h for this module consists of:

- weekly classes: 22.5h
- tutorials: 22.5h
- Work on assignment: 75h
- Literature study 30h
- preparation for and time of final exam: 30h

prerequisites for the module:

Basic knowledge in software engineering and in distributed systems as introduced, e.g., in the modules DSG-IDistrSys-B or DSG-DistrSys-M.

Recommended prior knowledge:

Basic knowledge in software engineering and distributed systems.

Module Introduction to Distributed Systems (DSG-IDistrSys) - recommended

Admission requirements:

none

Frequency: every summer semester

Recommended semester:

Minimal Duration of the Module:

1 Semester

Module Units

1. Lectures Service-Oriented Architecture and Web Services

Mode of Delivery: Lectures

Lecturers: Prof. Dr. Guido Wirtz, Scientific Staff Praktische Informatik

Language: English

Frequency: every summer semester

Learning outcome:

c.f. overall module description

Contents:

c.f. overall module description

Literature:

2,00 Weekly Contact Hours

<p>SOA is still a fast emerging field - most recent version of standards and up-to-date literature will be provided at the beginning of each course.</p>	
<p>2. Practicals Service-Oriented Architecture and Web Services Mode of Delivery: Practicals Lecturers: Scientific Staff Praktische Informatik Language: English/German Frequency: every summer semester</p> <hr/> <p>Learning outcome: c.f. overall module description</p> <hr/> <p>Contents: Introduction to and discussion of tools and practical issues closely related to the topics discussed in the lecture as well as solutions of problems that come up during working on the practical assignment.</p> <hr/> <p>Literature: c.f. overall module description</p>	<p>2,00 Weekly Contact Hours</p>
<p>Examination Coursework Assignment and Colloquium / Duration of Examination: 15 minutes Duration of Coursework: 3 months</p> <p>Description: Oral examination concerning the topics discussed in the lecture, exercises and assignment. Students may choose English or German as the language for the oral examination. Examinations will take place at the end of the summer term or at the begin of the winter term (students may choose one of them). Students are assumed to work on a programming assignment ('schriftliche Hausarbeit') during the semester that is introduced at the beginning of the semester and uses the most important technologies discussed during the semester.</p> <p>Note: Without working on the programming assignment over the term students may run into problems during their oral examination (Kolloquium) as we discuss questions concerning topics from the lectures as well as from the assignment; questions about the assignment are based on the assignment solution programmed by the students.</p>	

Module DSG-SRDS-M Selected Readings in Distributed Systems <i>Selected Readings in Distributed Systems</i>		3 ECTS / 90 h 23 h Präsenzzeit 67 h Selbststudium
(since WS18/19) Person responsible for module: Prof. Dr. Guido Wirtz		
Contents: This module is intended to offer an in-depth study of specific topics in distributed systems that go well beyond the topics discussed in DSG-IDistrSys, DSG-SOA-M or DSG-DSM-M. We try to close the gap between 'standard' lecture topics often dealing with the (required) basics and the state-of-the-art related to a specific research question regarding distributed systems in general, complex systems architecture, SOC and SOA, server-side middleware, cloud computing, process languages, as well as questions w.r.t. standard conformance, interoperability and correctness based on 'ground-breaking' as well as up-to-date research papers from international journals and/or conferences.		
Learning outcomes: Students will learn how to read and work on recent research papers and how to present their essence as an outline talk to colleagues (students). Students will be able to classify and compare results from papers in the context of a specific research question. Moreover, students will become proficient in the developments of the specialized research area that is the topic of the particular course.		
Remark: The main language of instruction in this course is English. The overall work load for the course is 90 hours: <ul style="list-style-type: none"> • 22.5 h classes • 55 h work on assigned readings, essay and presentations • 12.5 h preparation for and time of final exam Each student studies all readings (papers) assigned during the course, presents two papers in front of the class in a short outline talk (19 minutes), involves him/herself actively in discussions during classes and describes a selected topic discussed in class in a short essay (8 pages). Additionally, a final oral examination has to be taken at the end of term.		
prerequisites for the module: none		
Recommended prior knowledge: Basic knowledge about distributed systems as offered, e.g., by the course DSG-IDistrSys or similar knowledge. Dependend on the topic of the specific course, additional knowledge as discussed in DSG-SOA-M or DSG-DSAM-M may be required (ask if in doubt before enrolling in the course) Module Introduction to Distributed Systems (DSG-IDistrSys) - recommended		Admission requirements: none
Frequency: every semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
<p>Selected Readings in Distributed Systems</p> <p>Mode of Delivery: Lectures and Seminar</p> <p>Lecturers: Prof. Dr. Guido Wirtz, Scientific Staff Praktische Informatik</p> <p>Language: English</p> <p>Frequency: every semester</p> <hr/> <p>Learning outcome:</p> <p>c.f. overall module description</p> <hr/> <p>Contents:</p> <p>c.f. overall module description</p> <hr/> <p>Literature:</p> <p>c.f. overall module description</p>	<p>2,00 Weekly Contact Hours</p>
<p>Examination</p> <p>Coursework Assignment and Colloquium / Duration of Examination: 20 minutes Duration of Coursework: 4 months</p> <p>Description:</p> <p>Oral examination about the topics discussed during the term with a special emphasis on those topics, the examinee has presented during the course in her or his short presentations or their essay. The language for the oral examination is English.</p> <p>Students are assumed to read a set of papers during the semester which are introduced at the beginning of the semester and present the content of at least two papers in a short outline talk (10 minutes maximum) as basis for the discussion among the participants during class. Additionally, each student writes an essay (8 pages) that describes the essentials of one of the research topics discussed during class and relates this topic to the overall theme of the selected readings course.</p>	

Module DSG-Sem-M Master Seminar in Distributed Systems <i>Masterseminar zu Verteilten Systemen</i>		3 ECTS / 90 h
(since SS20) Person responsible for module: Prof. Dr. Guido Wirtz		
Contents: This module is intended to offer an in-depth study of specific topics in distributed systems that go well beyond the topics discussed in DSG-DistrSys-M, DSG-SOA-M or DSG-DSM-M. We try to close the gap between 'standard' lecture topics often dealing with the (required) basics and the state-of-the-art related to a specific research question regarding distributed systems in general, SOC and SOA, server-side middleware, process languages, as well as questions w.r.t. standard conformance, interoperability and correctness based on 'ground-breaking' as well as up-to-date research papers from international journals and/or conferences.		
Learning outcomes: Students will learn how to read and work on research papers, how to present their essence as an outline talk to colleagues (students) and how to guide discussion sessions based on scientific talks. Students will be able to classify and compare results from papers in the context of a specific research question. Moreover, students will become proficient in the developments of the specialized research area that is the topic of the particular course.		
Remark: The seminar will regularly be taught in English.		
prerequisites for the module: none		
Recommended prior knowledge: Basic knowledge about distributed systems as offered, e.g., by the course <i>DSG-IDistrSys-B</i> oder <i>DSG-DistrSys-M</i> or similar knowledge. Depend on the topic of the specific seminar, additional knowledge as discussed in DSG-SOA-M or DSG-DSAM-M may be helpful (ask if in doubt before enrolling in the course)		Admission requirements: none
Frequency: every semester	Recommended semester: 2.	Minimal Duration of the Module: 1 Semester

Module Units	
Master Seminar in Distributed Systems Mode of Delivery: Key competence Lecturers: Prof. Dr. Guido Wirtz Language: English/German Frequency: every semester	2,00 Weekly Contact Hours
Learning outcome: see module description	
Contents: see module description	

<p>Literature: depends on specific topics of each seminar and will be given in the introductory meeting</p>	
<p>Examination Coursework Assignment with presentation / Duration of Examination: 30 minutes Duration of Coursework: 4 months prerequisites for module examination: Regelmäßige Teilnahme an der Lehrveranstaltung Description: Review of a written elaboration on the most important aspects of the topic, including a correct list of references. Participation in peer reviewing the other participants; free holding of a a presentation based on presentation documents including discussion of the contents with the seminar participants.</p>	

Module EESYS-DAE-M Data Analytics in Energy Informatics <i>Data Analytics in der Energieinformatik</i>	6 ECTS / 180 h
(since WS19/20) Person responsible for module: Prof. Dr. Thorsten Staake	
<p>Contents:</p> <p>This course provides the theoretical foundation and conveys hands-on skills in the fields of data analytics and machine learning using the statistics software GNU R. It uses real-world datasets from the realm of energy efficiency and consumer behavior and conveys the subject matter through real-world examples and practical challenges.</p> <p>Following a refresher in descriptive statistic, the course covers</p> <ul style="list-style-type: none"> • an introduction to the statistics software GNU R, • the design of field experiments and the use of Information Systems to collect behavioral data, • techniques to formulate, solve, and interpret linear and logistic regression analyses, • techniques to formulate, solve, and interpret clustering analyses, • setting up, training, and evaluating machine learning algorithms, including KNN, regression, and support vector machines, and • ethical issues and data privacy regulations. 	
<p>Learning outcomes:</p> <p>After a successful participation in this course, participants can</p> <ul style="list-style-type: none"> • translate new business and research questions that can be answered using empirical methods into suitable experimental designs, • plan and conduct corresponding experiments, • choose suitable methods from the set of methods presented in class to analyze the data, • explain their design choices, the choice of methods, and the steps of the analyses, • apply the methods correctly and efficiently using the statistics software R, • adjust the methods if needed to solve new and specific problems based on an understanding of the necessary theories, • interpret the outcome of such analyses and identify the strengths and limitations of the approaches, and • reflect upon data protection, privacy and ethical issues related to powerful techniques for data acquisition and analytics. 	
<p>Remark:</p> <p>The lecture will be held as a self-paced, video-based online lecture.</p> <p>The tutorials take place once per week as in-classroom events.</p> <p>The online lecture includes instructional videos (scripted, i.e., with subtitles), reading material, exemplary data sets, and a multitude of online and offline tasks. It also includes an online discussion forum.</p> <p>The online lecture is supported by three classroom lectures (in addition to the classroom tutorials):</p> <ol style="list-style-type: none"> 1. Classroom lecture: The introductory event includes a course overview and motivation. Moreover, credentials to access the online resources will be announced. Date: First week of the semester. 	

<p>2. Classroom lecture: This intermediate session includes a review of the concepts covered so far. It should help participants to self-assess their learning progress. Date: Announced in the first week of the semester.</p> <p>3. Classroom lecture: Exam preparation and Q&A. Date: Last week of the semester.</p> <p>An introduction to the statistics software GNU R will be given as in-classroom event during the tutorials at the beginning of the semester.</p>		
prerequisites for the module:		
none		
Recommended prior knowledge:		Admission requirements:
<p>This course requires a basic understanding of statistics (e.g., from a bachelor-level course). A statistics repetition and is part of the online material of the course and the of the first tutorials and should be complemented in self-study if necessary.</p> <p>Basic familiarity with a programming language.</p>		none
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module:
		1 Semester

Module Units	
<p>1. Lectures Data Analytics in Energy Informatics</p> <p>Mode of Delivery: Lectures</p> <p>Lecturers: Prof. Dr. Thorsten Staake</p> <p>Language: German/English</p> <p>Frequency: every winter semester</p> <hr/> <p>Contents:</p> <p>The video-based online lecture is divided into two parts. Part 1 conveys the statistical basics required for the module, including, for example, properties of random distributions and descriptive and injunctive statistics. This part serves as refresher of bachelor-level statistics and thereby enables students with no statistics-knowledge beyond a basic introductory course to participate. Part 2 covers the methods outlined in "Module EESYS-DAE-M" subsection "Contents". It includes both, the theory behind the concepts and their application using R. Both, Part 1 and Part 2 use datasets and examples from industry and research and provides many hands-on examples. In order to deepen the understanding and to ease the transfer of the methods to new problems and settings, mini-tasks and small exercises are part of the online lecture.</p> <hr/> <p>Literature:</p> <p>Reading material will be announced in class.</p>	2,00 Weekly Contact Hours
<p>2. Practicals Data Analytics in Energy Informatics</p> <p>Mode of Delivery: Practicals</p> <p>Language: German/English</p> <p>Frequency: every winter semester</p> <hr/> <p>Contents:</p> <p>In the classroom tutorial, participants apply the methods, tools, and theories conveyed in the lecture to exemplary problems and to new challenges. This includes solving smaller tasks (e.g., acing case studies, working on concrete</p>	2,00 Weekly Contact Hours

data problems) on paper and using the statistics software GNU R. Tasks are addressed individually or in small teams.

The tutorials can also cover new content, especially when its immediate application supports the learning process. Selected tutorials contain a self-assessment of the learning progress.

An introduction to GNU R is given in the first sessions.

Examination

Written examination / Duration of Examination: 90 minutes

Description:

The examination covers subject matter taught in the lectures and tutorials. The examination can also cover transfers of the subject matter to new problems and settings. Students can achieve up to 90 points.

Through the voluntary completion of coursework ("bonus exercises") during the semester, participants can collect up to 12 additional points that are counted towards the exam, given that the exam is passed also without points from bonus exercises. Bonus exercises can take the form of written assignments, presentations, or smaller software projects. Points from bonus exercises are only valid in the semester they have been earned in and in the immediately following semester. In the first week of the course, the publishing dates of bonus exercise tasks, the submission deadlines, and the points per bonus exercise will be announced. It is possible to pass the exam with a grade of 1.0 also without points from bonus exercises.

Exam questions are stated in English, answers can be given in German or English.

Module EESYS-ES-M Energy Efficient Systems <i>Energieeffiziente Systeme</i>		6 ECTS / 180 h
(since WS19/20) Person responsible for module: Prof. Dr. Thorsten Staake		
<p>Contents:</p> <p>The course covers the design and application of Information Systems that help increase energy efficiency and reduce greenhouse gas emissions. It is directed to computer science and Information Systems students that want to apply their skills to challenges in the fields of energy, mobility, production, and sustainable consumption/consumer behavior.</p> <p>The course introduces methods and theories from behavioral economics, operations management, and simulation analysis that help to understand, analyze, and shape both, industry processes and consumer behavior in the field of sustainability. Also covered are cost/benefit considerations on a micro- and macro-level (including, for example, rebound effects) and a discussion on the economic and societal implications of the subject matter.</p> <p>The course includes an introduction to physics and energy engineering to allow students with very limited knowledge in these fields to participate successfully.</p>		
<p>Learning outcomes:</p> <p>Successful participants of this course shall acquire the skills to</p> <ul style="list-style-type: none"> • explain the physical and technical principals covered in this course and apply them to new problems, • explain the components, influencing factors, requirements and challenges related to electric mobility and describe the contribution that Information Systems can make to solve the challenges; moreover, successful participants shall be able to set up data-based simulations to derive important characteristic variables related to electric vehicles, such as electric reachability, peak loads to electric grids, etc., • outline, assess, and conceptually model the potential of Information Systems and the effects to heating and room climate applications, • explain in detail the characteristics of and implications from environmental business Information Systems, • explain the discussed behavioral theories (e.g., the prospect theory), make use of them when building Information Systems that support decision making and behavioral change, and be able to evaluate the effectiveness of such systems, and • evaluate the effects of the tools and methods introduced, including their micro- and macro-economic effects, and critically assess the techniques used to perform such evaluations. <p>Moreover, successful participants shall be able to apply the acquired skills to new challenges and adjust and extend them as needed.</p> <p>Finally, the participants shall realize the scope for design and the potential that results from their IT studies to favorably shape a sustainable and socially desirable development of our society.</p>		
prerequisites for the module: none		
Recommended prior knowledge: none		Admission requirements: none
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
<p>1. Lectures Energy Efficient Systems Mode of Delivery: Lectures Lecturers: Prof. Dr. Thorsten Staake Language: German/English Frequency: every summer semester</p> <hr/> <p>Contents: The lecture covers the topics mentioned in "Module EESYS-ES-M", subsection "Contents". It uses traditional lecture elements, discussions, exercises, and group work to support participants in reaching the learning objectives. Special emphasis is placed on working on cases and on discussions of studies and scientific publications. Methods, tools, and theories are introduced with references to practical challenges and are applied to exemplary problems. For selected topics, the lecture relies on flipped classroom elements for which participants need to acquire knowledge in advance (e.g., through reading tasks), which is then critically reflected and extended in the classroom sessions.</p> <hr/> <p>Literature: Weiterführende Unterlagen werden in der Veranstaltung bekanntgegeben.</p>	2,00 Weekly Contact Hours
<p>2. Practicals Energy Efficient Systems Mode of Delivery: Practicals Language: German/English Frequency: every summer semester</p> <hr/> <p>Contents: The first tutorials convey basics in physics and electrical engineering in order to also allow students who did not take related modules to participate in this course. Subsequently, participants apply the methods, tools, and theories conveyed in the lecture to exemplary problems and to new challenges. Tutorials include small tasks, case studies, and reviews of scientific publications that are addressed individually or in small teams. The tutorials can also cover new content, especially when its immediate application supports the learning process. Selected tutorials contain a self-assessment of the learning progress.</p> <hr/> <p>Literature: Reading material will be announced in class.</p>	2,00 Weekly Contact Hours

<p>Examination Written examination / Duration of Examination: 90 minutes Description: The examination covers subject matter taught in the lectures and tutorials. The examination can also cover transfers of the subject matter to new problems and settings. Students can achieve up to 90 points. Through the voluntary completion of coursework ("bonus exercises") during the semester, participants can collect up to 12 additional points that are counted</p>	
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towards the exam, given that the exam is passed also without points from bonus exercises. Bonus exercises can take the form of written assignments, presentations, or smaller software projects. Points from bonus exercises are only valid in the semester they have been earned in and in the immediately following semester. In the first week of the course, the publishing dates of bonus exercise tasks, the submission deadlines, and the points per bonus exercise will be announced. It is possible to pass the exam with a grade of 1.0 also without points from bonus exercises.

Exam questions are stated in English, answers can be given in German or English.

Module Gdl-AFP-M Advanced Functional Programming <i>Advanced Functional Programming</i>	6 ECTS / 180 h
(since SS20 to SS20) Person responsible for module: Prof. Ph.D. Michael Mendler	
Contents: Based on an existing basic knowledge of functional programming (FP), the aim of this module is to develop advanced skills in the use of FP languages to structure and solve algorithmic problems. We will study advanced programming abstractions specifically developed for the functional context as they are available as packages and frameworks in the toolbox of professional FP programmers. Following the methodological structure of the introductory course GDI-IFP, this advanced course, too, combines both practical programming with a focused discussion of pertinent underlying mathematical concepts. Though we use Haskell as our main language we may also look at other FP languages such as F#, ML or OCAML where appropriate.	
Learning outcomes: At the end of this course students should <ul style="list-style-type: none"> • be familiar with advanced FP programming concepts and their application (e.g., class mechanism, type families, higher-rank polymorphism, monad and arrow abstractions, lenses, continuation-style programming, stream programming, concurrency abstractions) • be able to use these advanced language concepts to solve complex algorithmic problems efficiently, in particular involving the use of memory, concurrency and interaction • be able use the Haskell stack build tool and understand the mechanisms of package management • appreciate the importance of functional abstraction for conciseness and efficiency of programming complex applications • be familiar with the second-order polymorphic lambda calculus (Hindley-Milner predicative let-polymorphism, impredicative System F) as an operational semantics behind (eager, lazy) functional programming • be able to explain the encoding of recursive data structures in type theory • have an elementary understanding of the execution model of functional languages and transformation to operational code through defunctionalisation and abstract machines. • by able to use FP (specifically Haskell) as a development tool for the design of new programming languages 	
Remark: The workload for this module splits up roughly like this: <ul style="list-style-type: none"> • participation in lectures and tutorials: 45 hrs • preparation of classes and tutorials as well literature research: 60 hrs • solving (ungraded) programming exercises and participation in lab sessions: 45 hrs • exam preparation: 30 hrs 	
prerequisites for the module: none	
Recommended prior knowledge:	Admission requirements: none

Elementary programming skills in a functional programming language, such as from module Gdl-IFP-B; English language skills at Level B2 (UniCert II) or above.		
Module Introduction to Functional Programming (Gdl-IFP) - recommended		
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
<p>1. Advanced Functional Programming</p> <p>Mode of Delivery: Lectures</p> <p>Lecturers: Prof. Ph.D. Michael Mendler</p> <p>Language: English/German</p> <p>Frequency: every summer semester</p> <hr/> <p>Contents:</p> <p>Through class presentations and direct interactions with the students the lecturer introduces the topics of the course in detail, poses exercises and suggests literature for self-study.</p> <hr/> <p>Literature:</p> <ul style="list-style-type: none"> • S. Marlow: The Haskell 2010 Language Report. https://www.haskell.org/onlinereport/haskell2010/ • V. Zsóok, Z. Horváth, R. Plasmeijer: Central European Functional Programming School. Springer 2012. • S. Marlow: Parallel and Concurrent Programming in Haskell: Techniques for Multicore and Multithreaded Programming, O'Reilly 2013. • B. O'Sullivan, J. Goerzen, D. Stewart: Real World Haskell. O'Reilly 2009. • Ch. Okasaki: Purely Functional Data Structures, CUP 1998 • F. Rabhi, G. Lapalme: Algorithms - A Functional Approach. • D. Syme, A. Granicz, A. Cisternino: Expert F#4.0, Apress 2015. • B. Pierce: Types and Programming Languages. MIT Press 2002. (esp. Chapters 23+25) • H. Barendregt, W. Dekkers, R. Statman: Lambda Calculus with Types. CUP 2013. 	2,00 Weekly Contact Hours
<p>2. Advanced Functional Programming</p> <p>Mode of Delivery: Practicals</p> <p>Lecturers: Prof. Ph.D. Michael Mendler</p> <p>Language: English/German</p> <p>Frequency: every summer semester</p> <hr/> <p>Contents:</p> <p>The tutorials deepen the students' understanding of the theoretical concepts and constructions covered in the lectures through practical exercises. Participants are given the opportunity to discuss their solutions to homework question sheets and sample solutions are presented by the tutors or lecturer for selected exercises. The tutorials also provide exam preparation.</p> <hr/> <p>Literature:</p>	2,00 Weekly Contact Hours

The literature will be announced in class. Here are some general pointers on FP languages and synchronous programming.

- S. Marlow: The Haskell 2010 Language Report. <https://www.haskell.org/onlinereport/haskell2010/>
- V. Zsók, Z. Horváth, R. Plasmeijer: Central European Functional Programming School. Springer 2012.
- S. Marlow: Parallel and Concurrent Programming in Haskell: Techniques for Multicore and Multithreaded Programming, O'Reilly 2013.
- D. Syme, A. Granicz, A. Cisternino: Expert F#4.0, Apress 2015.
- H. Barendregt, W. Dekkers, R. Statman: Lambda Calculus with Types. CUP 2013.
- Benveniste, A. et al: The Synchronous Languages 12 years later. Proc. IEEE, Vol 91(1), January 2003.
- Berry, G.: SCADE: Synchronous design and validation of embedded control software. In: Next Generation Design and Verification Methodologies for Distributed Embedded Control Systems. Proc. GM R&D Workshop, Bangalore, January 2007. pp. 19-33.
- Potop-Butucaru et. al: The Synchronous Hypothesis and Synchronous Languages. In Richard Zurawski. *Embedded Systems Design and Verification*, CRC Press, pp.6-1-6-27, 2009.

Examination

Written examination / Duration of Examination: 90 minutes

Description:

The examination language is English.

The form of examination is either oral (30 minutes) or written (90 minutes) depending on the number of participants. The form of examination will be determined at the beginning of the semester and announced in class.

Examination

Oral examination / Duration of Examination: 30 minutes

Description:

The examination language is English.

The form of examination is either oral (30 minutes) or written (90 minutes) depending on the number of participants. The form of examination will be determined at the beginning of the semester and announced in class.

Module Gdl-CSNL-M Computational Semantics of Natural Language <i>Computational Semantics of Natural Language</i>	6 ECTS / 180 h
(since SS19 to SS20) Person responsible for module: Prof. Ph.D. Michael Mendler further responsible : Luke Burke	
<p>Contents:</p> <p>The formal study of natural language syntax and semantics has developed as a very lively sub-field of linguistics in the past 50 years, with the typed lambda calculus in particular providing a way of giving compositional analyses of meanings in natural language. Recently, monads and continuations have been employed as tools in natural language syntax and semantics. The aim of this module is to introduce the use of monads and continuations in natural language semantics and to discuss different approaches to the formal representation of quantifier scope ambiguities in natural language. The basics of natural language semantics (typed lambda calculus) will be briefly introduced, before discussing a continuation-based approach to quantification in natural language, which will be contrasted with other approaches. Monads representing focus, intensionality and non-determinism in natural language will be discussed. We will look at how analyses of the meaning of sentences can be represented in Haskell.</p> <p>Importantly, the course may differ slightly from other courses in that assessment will not concentrate on technical exercises; rather, we require careful reading and dissection of relevant literature on the topic, since the primary mode of assessment will be via seminar presentations and essays, and you will be assessed on your understanding of, and your independent analysis of, relevant literature discussed in lectures. Independent reading of this literature will in fact be essential.</p> <p>This course may also be of interest to students in philosophy and linguistics.</p>	
<p>Learning outcomes:</p> <p>At the end of this course students should be familiar with different approaches to the formal representation of quantifier scope ambiguities in natural language; be familiar with how monads and continuations have been used in natural language semantics; be familiar with the use of Haskell to formalise analyses in natural language semantics; be able to produce and manipulate terms of the typed lambda calculus to represent how meanings combine; have an understanding of how both logics and trees have been used to represent natural language syntax; be acquainted with logics such as Montague's "Intensional Logic" and Gallin's Ty2.</p>	
<p>Remark:</p> <p>The workload for this module consists of:</p> <ul style="list-style-type: none"> • participation in lectures and seminar sessions: 45hrs • individual preparation and reading: 45hrs • essay writing and preparation of presentation: 60hrs • exam preparation and oral exam: 30hrs 	
<p>prerequisites for the module: none</p>	
<p>Recommended prior knowledge:</p> <p>Willingness to read relevant literature, critically discuss and analyse it and write about it. Basic logic (Gdl-Mfl-1: Mathematik für Informatiker) or an equivalent level of understanding. Some knowledge of</p>	<p>Admission requirements:</p> <p>English language skills at Level B2 (UniCert II) or above.</p>

modal logic more basic than that required for (Gdl-MTL: Modal and Temporal Logic). Knowledge of the typed lambda calculus (abstraction and application) and elementary Haskell (Gdl-IFP: Introduction to Functional Programming) would be very useful, though not essential.		
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: Semester

Module Units	
<p>Computational Semantics of Natural Language Language: English Frequency: every summer semester</p> <hr/> <p>Contents: Through prepared class presentations, essay writing, and direct interactions with the students the lecturer introduces the topics of the course in detail. The seminars deepen the students' understanding of the theoretical concepts and constructions covered in the lectures through presentations, which involve comparing alternative analyses of linguistic phenomena.</p> <hr/> <p>Literature:</p> <ul style="list-style-type: none"> • van Eijck, J. And Unger, Christina, "Computational Semantics with Functional Programming", Cambridge University Press 2010 • Barker, C. and Shan, C.-C., "Continuations and natural language", Volume 53. Oxford studies in Theoretical Linguistics, Oxford University Press, 2014 • Carpenter, Bob, "Type-Logical Semantics", MIT Press (1997) • Keenan, Edward, and Stabler, Edward, "Mathematical structures in Language", CSLI publications, Stanford, 2016 • Gallin, Daniel, "Intensional and Higher-Order Modal logic. North Holland, 1975. 	4,00 Weekly Contact Hours

<p>Examination Portfolio</p> <p>Description: The portfolio assessment consists of</p> <ul style="list-style-type: none"> • written essay (4000-5000 words) • class presentation (30 mins) • final oral exam (20 min) <p>Each portfolio part is graded individually. The grades are weighted as follows: 30% for essay, 20% for class presentation, 50% for final oral exam.</p>	
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Module Gdl-FP-M Functional Programming <i>Functional Programming</i>		6 ECTS / 180 h
(since WS19/20 to WS19/20) Person responsible for module: Prof. Ph.D. Michael Mendler		
Contents: The aim of this module is to provide an introduction to functional programming using Haskell. This course develops both elementary practical programming skills and discusses the typed lambda calculus and its role as an operational semantics for functional programming, stressing the importance of types and type checking for static program analysis.		
Learning outcomes: At the end of this course students should be familiar with important language constructs of Haskell and their semantics (e.g., expressions, local declarations, higher-order function abstraction, recursion, lazy and eager evaluation, referential transparency, algebraic data types, monads); be able to use these language concepts to solve algorithmic problems; be familiar with the lambda calculus as an operational semantics behind functional programming; understand the difference between imperative and declarative programming styles; have an appreciation of the close relationship between programming language types and specification and the role of type checking as a static program analysis method; be familiar with polymorphic Hindley-Milner style type systems.		
Remark: The main language of instruction in this course is English. However, the lectures and/or tutorials may be delivered in German if all participating students are fluent in German.		
prerequisites for the module: none		
Recommended prior knowledge: Elementary concepts in logic and discrete mathematics for computer scientists; Basic programming skills; English language skills at Level B2 (UniCert II) or above. Module Introduction to Algorithms, Programming and Software (DSG-EiAPS-B) - recommended Module Propositional and Predicate Logic (Gdl-Mfl-1) - recommended		Admission requirements: none
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
1. Functional Programming Mode of Delivery: Lectures Lecturers: Prof. Ph.D. Michael Mendler Language: English/German Frequency: every winter semester <hr/> Contents:	2,00 Weekly Contact Hours

<p>Through prepared class presentations and direct interactions with the students the lecturer introduces the topics of the course in detail, poses exercises and suggests literature for self-study.</p> <p>Literature:</p> <ul style="list-style-type: none"> • Pierce, B. C.: Types and Programming Languages, MIT Press, 2002 • Thompson, S.: Haskell – The Craft of Functional Programming, Addison-Wesley 1999. 	
<p>2. Functional Programming Mode of Delivery: Practicals Lecturers: Prof. Ph.D. Michael Mandler Language: English/German Frequency: every winter semester</p> <hr/> <p>Contents: The tutorials deepen the students' understanding of the theoretical concepts and constructions covered in the lectures through practical exercises. Participants are given the opportunity to discuss their solutions to homework question sheets and sample solutions are presented by the tutors or lecturer for selected exercises. The tutorials also provide exam preparation.</p>	<p>2,00 Weekly Contact Hours</p>
<p>Examination Written examination / Duration of Examination: 90 minutes</p> <p>Description: 90 min written examination. The exam takes place during the regular exam period after the end of the semester.</p>	

Module Gdl-Sem-M Master's Seminar Theoretical Computer Science		3 ECTS / 90 h
<i>Masterseminar Grundlagen der Informatik</i>		
(since WS17/18)		
Person responsible for module: Prof. Ph.D. Michael Mendler		
Contents:		
The Gdl seminar will be held on a semesterly basis on varying topics in the area of theoretical foundations of computer science.		
Learning outcomes:		
Ability to develop problem solutions from independent research into the current academic literature, specifically with focus on mathematical tools; Ability to communicate complex problem-solving approaches in writing and orally. Promotion of the scientific curiosity and the formation of a self-confident research attitude towards Computer Science Engineering.		
Remark:		
The written seminar essay and the presentation may be delivered in English or in German.		
prerequisites for the module:		
none		
Recommended prior knowledge:		Admission requirements:
Discrete Mathematics, elementary Logic and Algebra. Introduction to Theoretical Computer Sciences, Functional Programming; Distributed Systems; English language skills at level B2 (UniCert II) or above.		
Frequency: winter or summer semester, on demand	Recommended semester:	Minimal Duration of the Module:
		1 Semester

Module Units

Master's Seminar Theoretical Computer Science Mode of Delivery: Seminar Lecturers: Michael Mendler, N.N. Language: English/German Frequency: winter or summer semester, on demand	2,00 Weekly Contact Hours
Contents: The Gdl seminar will be held on a semesterly basis on varying topics in the area of theoretical foundations of computer science.	
Literature: Pertinent literature will be selected and announced during the first classes at the beginning of the semester.	
Examination Coursework Assignment with presentation / Duration of Examination: 30 minutes Duration of Coursework: 4 months prerequisites for module examination: Regelmäßige Teilnahme an der Lehrveranstaltung Description:	

The examination language will be announced in the first course.

Module HCI-MCI-M Human-Computer Interaction <i>Mensch-Computer-Interaktion</i>		6 ECTS / 180 h
(since SS20) Person responsible for module: Prof. Dr. Tom Gross		
Contents: Advanced theoretical, methodological, and practical foundation of Human-Computer Interaction		
Learning outcomes: The aim of this module is to teach advanced knowledge and skills in the area of human-computer interaction as well as a broad theoretical and practical methodological expertise concerned with the design, conception, and evaluation of ubiquitous systems. Students of this course learn the relevant literature and systems in breadth and depth and are later able to critical review new literature and systems.		
Remark: http://www.uni-bamberg.de/hci/leistungen/studium The workload for this module is roughly structured as following: <ul style="list-style-type: none"> • Attendance of the lectures and assignments: 45 hours • Credits of the lecture (incl. research and study of additional sources): ca. 30 hours • Credits of the assignments (incl. research and study of additional sources, but without optional homework assignment): ca. 30 hours • Solving the optional homework assignments: overall ca. 45 hours • Exam preparation: ca. 30 hours (based on the above mentioned preparation and revision of the subject material) The default language of instruction in this course is German, but can be changed to English on demand. All course materials (incl. exams) are available in English.		
prerequisites for the module: none		
Recommended prior knowledge: Module Algorithms and data structures (MI-AuD-B) Module Introduction to Algorithms, Programming and Software (DSG-EiAPS-B)		Admission requirements: Passing the written exam
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
Human - Computer Interaction Mode of Delivery: Lectures Lecturers: Prof. Dr. Tom Gross Language: German/English Frequency: every summer semester	2,00 Weekly Contact Hours
Contents: After an introduction into the subject the following topics are covered in this lecture: <ul style="list-style-type: none"> • Mobile human-computer interaction 	

<ul style="list-style-type: none"> • Adaptivity and adaptability • Information visualisation • Tangible user interaction • Usability engineering • Usability and economics 	
<p>Literature:</p> <p>The course is based on a compilation of different sources; as additional sources and as a reference are recommended:</p> <ul style="list-style-type: none"> • Jacko, J.A. and Sears, A., (Eds.). Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications. Lawrence Erlbaum, Hillsdale, NJ, 2002. • Hammond, J., Gross, T. and Wesson, J., (Eds.). Usability: Gaining a Competitive Edge. Kluwer Academic Publishers, Dordrecht, 2002. 	
<p>Examination</p> <p>Oral examination / Duration of Examination: 30 minutes</p> <p>Description:</p> <p>The oral exam takes 30 minutes and is worth a total of 90 points. Depending on the number of attendees the form of the exam can be changed to a written exam with 90 minutes and a total of 90 points. The final form of the exam is announced in the first lecture at the beginning of the term.</p> <p>During the semester students can do assignments, which are optional. They are 12 points in total. The type of optional homework assignments as well as the deadlines are announced in detail at the beginning of the term. If the oral exam is passed (as a rule 50% of the points have to be reached) the points from the assignments are a bonus and added to the points from the oral exam. In any case, a top grade of 1,0 is also reachable without solving the assignments.</p>	
<p>Module Units</p>	
<p>Human-Computer Interaction</p> <p>Mode of Delivery: Practicals</p> <p>Lecturers: Scientific Staff Mensch-Computer-Interaktion</p> <p>Language: German/English</p> <p>Frequency: every summer semester</p> <hr/> <p>Contents:</p> <p>Practical assignments based on the subjects of the lecture.</p> <hr/> <p>Literature:</p> <p>Cf. lecture</p>	<p>2,00 Weekly Contact Hours</p>
<p>Examination</p> <p>Written examination / Duration of Examination: 90 minutes</p> <p>Description:</p> <p>In Abhängigkeit von der Teilnehmerzahl wird die Modulprüfung entweder in Form einer Klausur oder in Form einer mündlichen Prüfung</p>	

durchgeführt. Die Festlegung erfolgt zu Semesterbeginn und wird im ersten Lehrveranstaltungstermin bekannt gegeben.

In der Klausur über 90 min. können 90 Punkte erzielt werden.

Es besteht die Möglichkeit, optionale Studienleistungen zu erbringen. Diese umfassen insgesamt 12 Punkte. Die Art der optionalen Studienleistungen sowie deren Bearbeitungsfrist werden zu Beginn der Lehrveranstaltung verbindlich bekannt gegeben. Ist die Klausur bestanden (in der Regel sind hierzu 50 % der Punkte erforderlich), so werden die durch optionale Studienleistungen erreichten Punkte als Bonuspunkte angerechnet. Eine 1,0 ist in der Klausur auf jeden Fall auch ohne Punkte aus der Bearbeitung optionaler Studienleistungen erreichbar.

Module HCI-Prop-M Propaedeutic: Human-Computer-Interaction <i>Propädeutikum Mensch-Computer-Interaktion</i>		3 ECTS / 90 h
(since WS17/18) Person responsible for module: Prof. Dr. Tom Gross		
Contents: Scientific foundation of the research field of Human-Computer Interaction		
Learning outcomes: The aim of this module is a general introduction to and teaching of fundamental paradigms and scientific methods of the organisation, the written documentation, oral presentation of research activities in Human-Computer Interaction. The primary focus is on domain-specific documentation and presentation of designs, prototypes, and user studies.		
Remark: http://www.uni-bamberg.de/hci/leistungen/studium The workload for this module is roughly structured as following: <ul style="list-style-type: none"> • Participation in the course meetings (theoretical foundation; practical case studies): ca. 30 hours • Working on the case studies: ca. 30 hours • Preparation of presentation: ca. 15 hours • Writing of term paper: ca. 15 hours The default language of instruction in this course is German, but can be changed to English on demand. All course materials (incl. exams) are available in English.		
prerequisites for the module: none		
Recommended prior knowledge: none		Admission requirements: none
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
Propaedeutic: Human-Computer-Interaction Mode of Delivery: Seminar Lecturers: Prof. Dr. Tom Gross, Scientific Staff Mensch-Computer-Interaktion Language: German/English Frequency: every winter semester	2,00 Weekly Contact Hours
Contents: This seminar is concerned with the documentation and presentation of current concepts, technologies, and tools and user studies of human-computer interaction.	
Literature: The course is based on a compilation of different sources; as additional sources and as a reference are recommended:	

Jacko, Julie A., ed. Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications. (3rd ed.). Lawrence Erlbaum, Hillsdale, NJ, 2012.

Examination

Coursework Assignment with presentation / Duration of Examination: 30 minutes

Duration of Coursework: 4 months

Description:

Written term paper and presentation on the chosen topic by the participant, incl. discussion

Module HCI-Sem-HCC-M Master-Seminar Human-Centred Computing		3 ECTS / 90 h
<i>Masterseminar Human-Centred Computing</i>		
(since WS17/18)		
Person responsible for module: Prof. Dr. Tom Gross		
Contents: Advanced active scientific work on own current concepts, technologies and tools of Human-Computer Interaction		
Learning outcomes: The aim of this course is the acquisition of abilities that allow the independent research and presentation of topics in the field of human-computer interaction on basis of the existing literature. The focus lies on the development of skills that allow to critically and systematically review literature in order to develop and present an own perspective.		
Remark: http://www.uni-bamberg.de/hci/leistungen/studium The workload for this module is roughly structured as following: <ul style="list-style-type: none"> • Participation in the seminars (introduction to the topics, discussions, presentations): ca. 20 hours • Literature review and getting familiar with the topic: ca. 25 hours • Preparation of presentation: ca. 15 hours • Writing of term paper: ca. 30 hours The default language of instruction is German and can be changed to English based on students' needs. All course materials (incl. exams) are available in English		
prerequisites for the module: none		
Recommended prior knowledge: Module Human-Computer Interaction (HCI-MCI-M)		Admission requirements: Passing the exam
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
Human-Centred Computing Mode of Delivery: Seminar Lecturers: Prof. Dr. Tom Gross, Scientific Staff Mensch-Computer-Interaktion Language: German/English Frequency: every summer semester	2,00 Weekly Contact Hours
Contents: This seminar is concerned with novel research methods in the fields of human-computer interaction, computer-supported cooperative work, and ubiquitous computing.	
Literature: To be announced at the beginning of the course	
Examination	

Coursework Assignment with presentation / Duration of Examination: 30 minutes

Duration of Coursework: 4 months

Description:

Written term paper and presentation on the chosen topic by the participant, incl. discussion

Module HCI-Sem-M Master-Seminar Human-Computer Interaction		3 ECTS / 90 h
<i>Masterseminar Mensch-Computer-Interaktion</i>		
(since WS17/18)		
Person responsible for module: Prof. Dr. Tom Gross		
Contents: Advanced active scientific work on current concepts, technologies and tools of Human-Computer Interaction		
Learning outcomes: The aim of this course is the acquisition of abilities that allow the independent research and presentation of topics in the field of human-computer interaction on basis of the existing literature. The focus lies on the development of skills that allow to critically and systematically review literature in order to develop and present an own perspective.		
Remark: http://www.uni-bamberg.de/hci/leistungen/studium The workload for this module is roughly structured as following: <ul style="list-style-type: none"> • Participation in the seminars (introduction to the topics, discussions, presentations): ca. 20 hours • Literature review and getting familiar with the topic: ca. 25 hours • Preparation of presentation: ca. 15 hours • Writing of term paper: ca. 30 hours The default language of instruction in this course is German, but can be changed to English on demand. All course materials (incl. exams) are available in English.		
prerequisites for the module: none		
Recommended prior knowledge: Module Human-Computer Interaction (HCI-MCI-M)		Admission requirements: Passing the exam
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module: 1 Semester
Module Units		
Human-Computer Interaction Mode of Delivery: Seminar Lecturers: Prof. Dr. Tom Gross, Scientific Staff Mensch-Computer-Interaktion Language: German/English Frequency: every winter semester		2,00 Weekly Contact Hours
Contents: This seminar is concerned with topics on current concepts, technologies, and tools of human-computer interaction.		
Literature: To be announced at the beginning of the course		
Examination Coursework Assignment with presentation / Duration of Examination: 30 minutes		

Duration of Coursework: 4 months

Description:

Written term paper and presentation on the chosen topic by the participant, incl. discussion

Module HCI-US-B Ubiquitous Systems <i>Ubiquitäre Systeme</i>		6 ECTS / 180 h
(since SS20) Person responsible for module: Prof. Dr. Tom Gross		
Contents: Theoretical, methodological, and practical foundation of Ubiquitous Computing		
Learning outcomes: The aim of this module is to teach advanced knowledge and skills in the area of ubiquitous systems as well as abroad theoretical and practical methodological expertise concerned with the design, conception and evaluation of ubiquitous systems. Students of this course learn the relevant literature and systems in breadth and depth and should be able to critical review new literature and systems		
Remark: http://www.uni-bamberg.de/hci/leistungen/studium The workload for this module is roughly structured as following: <ul style="list-style-type: none"> • Attendance of the lectures and assignments: 45 hours • Credits of the lecture (incl.research and study of additional sources): ca. 30 Hours • Credits of the assignments ((incl.research and study of additional sources, excluding optional homework assignment): ca. 30 hours • Solving the optional homework assignments: overall ca. 45 hours • Exam preparation: ca. 30 hours (based on the above mentioned preparation and revision of the subject material) The default language of instruction in this course is German, but can be changed to English on demand. All course materials (incl. exams) are available in English.		
prerequisites for the module: none		
Recommended prior knowledge: Module Algorithms and data structures (MI-AuD-B) Module Introduction to Algorithms, Programming and Software (DSG-EiAPS-B)		Admission requirements: Passing the written exam
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
Ubiquitous Systems Mode of Delivery: Lectures Lecturers: Prof. Dr. Tom Gross Language: German/English Frequency: every winter semester	2,00 Weekly Contact Hours
Contents: This lecture gives an introduction to the subject of Ubiquitous Computing—that is, the paradigm of invisible computing, with computers embedded into everyday objects that act as client and server and communicate with each other—and includes the following conceptual, technical and methodological topics:	

<ul style="list-style-type: none"> • Basic concepts • Base technology and infrastructures • Ubiquitous systems and prototypes • Context awareness • User interaction • Ubiquitous systems in a broad context and related topics 	
<p>Literature: The course is based on a compilation of different sources; as additional sources and as a reference are recommended:</p> <ul style="list-style-type: none"> • Krumm, J. (Ed.). Ubiquitous Computing Fundamentals. Taylor & Francis Group, Boca Raton, FL, 2010. 	
<p>Examination Oral examination / Duration of Examination: 30 minutes</p> <p>Description: The oral exam takes 30 minutes and is worth a total of 90 points. Depending on the number of attendees the form of the exam can be changed to a written exam with 90 minutes and a total of 90 points. The final form of the exam is announced in the first lecture at the beginning of the term.</p> <p>During the semester students can do assignments, which are optional. They are 12 points in total. The type of optional homework assignments as well as the deadlines are announced in detail at the beginning of the term. If the oral exam is passed (as a rule 50% of the points have to be reached) the points from the assignments are a bonus and added to the points from the oral exam. In any case, a top grade of 1,0 is also reachable without solving the assignments.</p>	
<p>Module Units</p>	
<p>Ubiquitous Systems Mode of Delivery: Practicals Lecturers: Scientific Staff Mensch-Computer-Interaktion Language: German/English Frequency: every winter semester</p> <hr/> <p>Contents: Practical assignments based on the subjects of the lecture including the programming of small prototypes</p> <hr/> <p>Literature: Cf. lecture</p>	<p>2,00 Weekly Contact Hours</p>
<p>Examination / Duration of Examination: 90 minutes</p> <p>Description: In Abhängigkeit von der Teilnehmerzahl wird die Modulprüfung entweder in Form einer Klausur oder in Form einer mündlichen Prüfung durchgeführt. Die Festlegung erfolgt zu Semesterbeginn und wird im ersten</p>	

Lehrveranstaltungstermin bekannt gegeben.

In der Klausur über 90 min. können 90 Punkte erzielt werden.

Es besteht die Möglichkeit, optionale Studienleistungen zu erbringen. Diese umfassen insgesamt 12 Punkte. Die Art der optionalen Studienleistungen, die Punkte pro optionaler Studienleistung sowie deren Bearbeitungsfrist werden zu Beginn der Lehrveranstaltung verbindlich bekannt gegeben. Ist die Klausur bestanden (in der Regel sind hierzu 50 % der Punkte erforderlich), so werden die durch optionale Studienleistungen erreichten Punkte als Bonuspunkte angerechnet. Eine 1,0 ist in der Klausur auf jeden Fall auch ohne Punkte aus der Bearbeitung optionaler Studienleistungen erreichbar.

Module KTR-GIK-M Foundations of Internet Communication <i>Grundbausteine der Internet-Kommunikation</i>	6 ECTS / 180 h 45 h Präsenzzeit 135 h Selbststudium
(since SS20) Person responsible for module: Prof. Dr. Udo Krieger	
<p>Contents:</p> <p>The course provides an introduction to the theoretical foundations of important technical issues related to the fundamentals of Internet communication, the data link layer, routing and transport protocols in IP networks, as well as advanced topics such as real-time communication and security in IP networks. The implementation of the learnt concepts in terms of predetermined configuration tasks in the communication laboratory by small teams of students constitutes the tutorial part of the course. For this purpose, guidelines, technical instructions, and tools will be provided.</p> <p>The implementation tasks include the configuration and testing of computer networks in the laboratory setting. Operating system and required software components like Wireshark, Atheris and Vyatta software router will be provided. The basic handling of the hardware and software itself will be performed by the students as part of their individual intellectual efforts within the course.</p>	
<p>Learning outcomes:</p> <p>The important skill to provide a qualified assessment of current communication technologies and corresponding practical knowledge can only be acquired by team-oriented processes subject to time constraints and the clear specification of technical and administrative objectives. In the course Foundations of Internet Communication and its tutorials in the router laboratory students will learn to work independently with a high level of responsibility as self-confident member of a successful team.</p> <p>It is the objective of the course that the students acquire practical knowledge on modern data communication in Internet and learn how communication concepts can be developed, implemented and judged with the highest level of expertise.</p> <p>The course is open to bachelor students in their transition phase to the master program. It attempts to prepare for the job in communication industry related fields. Master students in the first semester and exchange students from abroad are invited to join the course.</p>	
<p>Remark:</p> <p>The module can be selected by exchange students and master students speaking only English.</p> <p>The workload is composed of the following items:</p> <ul style="list-style-type: none"> • participation in lectures, tutorials in the laboratory, laboratory meetings: 45 hours • preparation, execution, post-processing of lectures and tutorials in the laboratory: 100 hours • preparation of the examination: 35 hours 	
<p>prerequisites for the module: none</p>	
<p>Recommended prior knowledge:</p> <ul style="list-style-type: none"> • data communication similar to module KTR-Datkomm-B • fundamental knowledge on programming in JAVA (or C++) • working knowledge on LINUX is recommended, but not assumed <p>Module Algorithms and Data Structures (AI-AuD-B) - recommended</p>	<p>Admission requirements: governed by examination regulations (StuFPO)</p>

Module Introduction to Algorithms, Programming and Software (DSG-EiAPS-B) - recommended		
Module Data communication (KTR-Datkomm-B) - recommended		
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
<p>Foundations of Internet Communication Mode of Delivery: Lectures and Practicals Lecturers: Prof. Dr. Udo Krieger Language: English/German Frequency: every summer semester</p> <hr/> <p>Learning outcome: The important skill to provide a qualified assessment of current communication technologies and corresponding practical knowledge can only be acquired by team-oriented processes subject to time constraints and the clear specification of technical and administrative objectives. In the course Foundations of Internet Communication and its tutorials in the router laboratory students will learn to work independently with a high level of responsibility as self-confident member of a successful team. It is the objective of the course that the students acquire practical knowledge on modern data communication in Internet and learn how communication concepts can be developed, implemented and judged with the highest level of expertise. The course is open to bachelor students in their transition phase to the master program. It attempts to prepare for the job in communication industry related fields. Master students in the first semester and exchange students from abroad are invited to join the course.</p> <hr/> <p>Contents: The course provides an introduction to the theoretical foundations of important technical issues related to the fundamentals of Internet communication, the data link layer, routing and transport protocols in IP networks, as well as advanced topics such as real-time communication and security in IP networks. The implementation of the learnt concepts in terms of predetermined configuration tasks in the communication laboratory by small teams of students constitutes the tutorial part of the course. For this purpose, guidelines, technical instructions, and tools will be provided. The implementation tasks include the configuration and testing of computer networks in the laboratory setting. Operating system and required software components like Wireshark, Atheros and Vyatta software router will be provided. The basic handling of the hardware and software itself will be performed by the students as part of their individual intellectual efforts within the course. The organization of the laboratories is following the framework of industry. It comprises definition, preparation, implementation and presentation phases. An incremental processing is performed like in industrial projects. It means</p> <ul style="list-style-type: none"> • a segmentation into specific work packages, 	4,00 Weekly Contact Hours

<ul style="list-style-type: none"> • its division into tasks and subtasks including milestones • the presentation of intermediate results • a final report with presentation <p>Further laboratories related to current research issues in "Future Generation Internet" will be integrated into the course on demand. Details are discussed in the first lecture.</p> <p>An actual list of studied topics and related references are presented in the first lecture.</p> <p>The language of the course will be announced during the first lecture.</p>	
<p>Literature:</p> <p>Foundations:</p> <ul style="list-style-type: none"> • J. Liebeherr, M. Elzarki: Mastering Networks, An Internet Lab Manual, Pearson Education, Boston, 2004. <p>Further references related to specific workpackages:</p> <ul style="list-style-type: none"> • Kurose, J., Ross, K.W.: Computer Networking – a Top-Down Approach, Addison-Wesley, 2013 . • Tanenbaum, A. S.: Computer Networks, Pearson Education, 2010. • Leon-Garcia, A., Widjaja, I.: Communication Networks, McGraw-Hill, Boston, 2nd ed. 2004. • Flaig, G., u.a.: Internet-Telefonie, Open source Press, München, 2006. <p>An up-to-date list is provided by the course.</p>	
<p>Examination</p> <p>Coursework Assignment and Colloquium / Duration of Examination: 30 minutes Duration of Coursework: 4 months</p> <p>Description:</p> <p>The evaluation of the course will take place after completion of all lectures within the examination cycle. It is based on following items:</p> <ul style="list-style-type: none"> • assessment of the chapters composed by the candidate in the final course report about all workpackages written by a team of students • presentation and explanation of specific tasks and outcomes of laboratories by an individual colloquium lasting 30 minutes <p>The evaluation rules of these components will be announced during the first lecture. The overall individual grading has to reach the level "satisfactory/ ausreichend (4.0)" to pass the examination of the module.</p> <p>The language of the examination will be announced during the first lecture.</p>	

Module KTR-MAKV-M Modeling and Analysis of Communication Networks and Distributed Systems <i>Modellierung und Analyse von Kommunikationsnetzen und Verteilten Systemen</i>		6 ECTS / 180 h 45 h Präsenzzeit 135 h Selbststudium
(since WS17/18) Person responsible for module: Prof. Dr. Udo Krieger		
Contents: The course deals with the analysis and performance evaluation of complex distributed systems such as telecommunication systems, computer networks and complex networks as well as cloud computing systems. The latter are transformed to abstract system-theoretical models and their associated parameters. The models are used to analyze the system behavior, and to predict relevant performance metrics such as utilization, throughput, waiting and response times of request, person or data flows in distributed systems or social networks. Such predictions have great importance regarding economic or technical design and decision processes in future generation networks and their distributed service architectures. The course presents the modeling of distributed systems and discusses associated description methods such as relevant load and machine models. The system-theoretical analysis of these models and the included resource assignment and management strategies are sketched based on simple analytic methods like Markov chains, algebraic and numerical solution methods for queueing models.		
Learning outcomes: It is the objective of the course to teach students the fundamentals of measurement, analysis, and performance evaluation methods in modern computer and communication networks, and distributed systems. Students will learn how they can apply the underlying system-theoretical monitoring, modeling, and analysis techniques to a given technical context. The application of the sketched models and methods is illustrated by exercises covering views of distributed systems with a realistic characteristic. Students are encouraged to apply a given methodology to new technical contexts and scientific tasks.		
Remark: The module can be selected by exchange students and master students speaking only English.		
prerequisites for the module: none		
Recommended prior knowledge: <ul style="list-style-type: none"> • solid knowledge of calculus (like Mathematik I) and linear algebra (like Mathematik für Informatik 2) • basic knowledge of probability theory and statistics • programming experience in JAVA (or C++) 		Admission requirements: governed by examination regulations (StuFPO)
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester
Module Units		
Modeling and Analysis of Communication Networks and Distributed Systems Mode of Delivery: Lectures and Practicals Lecturers: Prof. Dr. Udo Krieger		4,00 Weekly Contact Hours

Language: English/German

Frequency: every summer semester

Learning outcome:

It is the objective of the course to teach students the fundamentals of measurement, analysis, and performance evaluation methods in modern computer and communication networks, and distributed systems. Students will learn how they can apply the underlying system-theoretical monitoring, modeling, and analysis techniques to a given technical context. The application of the sketched models and methods is illustrated by exercises covering views of distributed systems with a realistic characteristic. Students are encouraged to apply a given methodology to new technical contexts and scientific tasks.

Contents:

The course deals with the analysis and performance evaluation of complex distributed systems such as telecommunication systems, computer networks and complex networks. The latter are transformed to abstract system-theoretical models and their associated parameters. The models are used to analyze the system behavior, and to predict relevant performance metrics such as utilization, throughput, waiting and response times of request, person or data flows in distributed systems or social networks. Such predictions have great importance regarding economic or technical design and decision processes in future generation networks and their distributed service architectures.

The course presents the modeling of distributed systems and discusses associated description methods such as relevant load and machine models. The system-theoretical analysis of these models and the included resource assignment and management strategies are sketched based on simple analytic methods like Markov chains, algebraic and numerical solution methods for queueing models, and simulative analysis schemes.

The content of the lectures is illustrated by exercises and laboratories covering important performance aspects in high-speed networks and distributed systems. Knowledge and skills to perform an efficient system analysis, system monitoring, and performance evaluation will be trained in this manner. The independent processing of tasks, the qualified presentation and critical discussion of the outcomes by teams of students is part of the course. It improves the technical understanding and provides means to work as project leader in industry on those topics.

The language of the course will be announced during the first lecture.

Literature:

- G. Bolch, S. Greiner, H. de Meer, K. S. Trivedi: Queueing Networks and Markov Chains. Wiley, 2nd ed., 2006.
- R. Nelson: Probability, Stochastic Processes, and Queueing Theory. Springer, 1995.

A list of further references is presented in the first lecture.

Examination

Oral examination / Duration of Examination: 30 minutes

Description:

30 minutes oral examination related to the technical topics of all lectures and practicals.

The language of the examination will be announced during the first lecture.

Module KTR-MMK-M Multimedia Communication in High Speed Networks <i>Multimedia-Kommunikation in Hochgeschwindigkeitsnetzen</i>	6 ECTS / 180 h 45 h Präsenzzeit 135 h Selbststudium
(since WS17/18) Person responsible for module: Prof. Dr. Udo Krieger	
<p>Contents:</p> <p>Based on the foundations of data communication, this advanced course of the master program presents the design of high-speed networks (HSN) and the advanced protocol elements of the signaling and user plane that are required to implement new real-time and multimedia services. It includes the digital switching technologies and protocol stacks of HSNs, the quality-of-service architectures, as well as the traffic management protocols of these next generation IP networks. The extension of the TCP/IP protocol stack to realize communication relations among mobile or stationary end systems that are supported by quality-of-service guarantees and associated improved switching concepts are discussed in detail by lectures of the course.</p> <p>These lectures focus on effective access technologies and new transport and QoS-architectures in the core network like Diffserv, MPLS and GMPLS. Further, enhancement of IPv4 by IPv6 switching and the extension of TCP by modern multipath concepts such as MPTCP and SCTP are presented. Advanced QoS-management concepts, effective resource and traffic management schemes like buffer management by RED, RIO or scheduling by WFQ, are discussed, too. Furthermore, we present new architectures for next generation networks (NGNs) such as software-defined networks and information-centric networks.</p> <p>Modern multimedia service architectures with interactive applications for third to fourth generation Internet like Web applications based on HTTP 2.0, WebRTC, peer-to-peer VoIP and media streaming applications are sketched.</p> <p>The course can be supplemented by the module Foundations of Internet Communication (KTR-GIK-M) with its instructive tasks executed in the router laboratory, by master seminars and projects or a master thesis on related topics in next generation networks.</p>	
<p>Learning outcomes:</p> <p>The students will be enabled to work independently according to the highest scientific standards on design and analysis tasks associated with high-speed network protocols. They will learn about the fundamentals of multimedia communication in high-speed networks and the systematic analysis of the applied communication algorithms by means of an interactive tutorial concept. They will assess the implementations of existing network protocols and to evaluate their performance by means of a measurement analysis with Wireshark and other tools. The processing of the design, assessment, measurement, and implementation tasks will be performed by teams of students. Thus, learning effective teamwork is part of the course.</p>	
<p>Remark:</p> <p>The module can be selected by exchange students and master students speaking only English.</p>	
<p>prerequisites for the module:</p> <p>none</p>	
<p>Recommended prior knowledge:</p>	<p>Admission requirements:</p> <p>governed by examination regulations (StuFPO)</p>

<ul style="list-style-type: none"> • successful examination in data communication similar to module KTR-Datkomm-B and substantial knowledge of related technical concepts • knowledge in programming with JAVA (or C++) 		
Module Advanced Java Programming (DSG-AJP-B) - recommended Module Data communication (KTR-Datkomm-B) - recommended		
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
<p>Multimedia Communication in High Speed Networks Mode of Delivery: Lectures and Practicals Lecturers: Prof. Dr. Udo Krieger Language: English/German Frequency: every summer semester</p> <hr/> <p>Learning outcome: The students will be enabled to work independently according to the highest scientific standards on design and analysis tasks associated with high-speed network protocols. They will learn about the fundamentals of multimedia communication in high-speed networks and the systematic analysis of the applied communication algorithms by means of an interactive tutorial concept. They will assess the implementations of existing network protocols and to evaluate their performance by means of a measurement analysis with Wireshark and other tools. The processing of the design, assessment, measurement, and implementation tasks will be performed by teams of students. Thus, learning effective teamwork is part of the course.</p> <hr/> <p>Contents: Based on the foundations of data communication, this advanced course of the masters programme presents the design of high-speed networks (HSN) and the advanced protocol elements of the signaling and user plane that are required to implement new real-time and multimedia services. It includes the digital switching technologies and protocol stacks of HSNs, the quality-of-service architectures, as well as the traffic management protocols of these next generation IP networks. The extension of the TCP/IP protocol stack to realize communication relations among mobile or stationary end systems that are supported by quality-of-service guarantees and associated improved switching concepts are discussed in detail by lectures of the course. These lectures focus on effective access technologies and new transport and QoS-architectures in the core network like Diffserv, MPLS and GMPLS. Further, the enhancement of IPv4 by IPv6 switching and the extension of TCP by modern multipath concepts such as MPTCP and SCTP are presented. Advanced QoS-management concepts, effective resource and traffic management schemes like buffer management by RED, RIO or scheduling by weighted fair queueing (WFQ), are discussed, too. Furthermore, we present new architectures for next generation networks (NGNs) such as software-defined networks and information-centric networks.</p>	4,00 Weekly Contact Hours

Modern multimedia service architectures with interactive applications for third to fourth generation Internet like Web applications based on HTTP 2.0, WebRTC, peer-to-peer VoIP and media streaming applications are sketched. The content of the lectures is illustrated by exercises and laboratories covering important aspects of the protocol stacks in high-speed networks. The independent processing of tasks, the qualified presentation and critical discussion of the outcomes by teams of students is part of the course. It improves the technical understanding and provides means to work as project leader in industry on those topics.

The course can be supplemented by the module Foundations of Internet Communication (KTR-GIK-M) with its instructive tasks executed in the router laboratory, by master seminars and projects or a master's thesis on related topics in next generation networks.

The language of the course will be announced during the first lecture.

Literature:

- Kurose, J., Ross, K.W.: Computernetzwerke – ein Top-Down-Ansatz mit Schwerpunkt Internet, Pearson Studium, München, 2013.
- Kurose, J.F., Ross, K.W.: Computer Networking, A Top-Down Approach Featuring the Internet, Pearson Addison-Wesley, 7th ed., 2017.
- Leon-Garcia, A., Widjaja, I.: Communication Networks, McGraw-Hill, Boston, 2nd ed. 2004.
- Comer, D.: Computernetzwerke und Internets, Pearson Studium, München, 2001.

Weitere Literatur wird in der Vorlesung benannt.

Examination

Oral examination / Duration of Examination: 30 minutes

Description:

30 minutes oral examination related to the technical topics of all lectures and practicals.

The language of the examination will be announced during the first lecture.

Module KTR-Mobi-M Mobile Communication <i>Mobilkommunikation</i>	6 ECTS / 180 h 45 h Präsenzzeit 135 h Selbststudium
(since SS20) Person responsible for module: Prof. Dr. Udo Krieger	
<p>Contents:</p> <p>The course presents the fundamentals of mobile communication. We sketch the underlying standards, system architectures and their realizations as well as current research and development trends. Due to the complexity of the field the course can only present some basic important aspects of those mobile communication systems that exhibit the strongest growth in the markets and affect all business areas of the information societies at most. The course will focus on the technical system and design perspectives regarding the service architectures and local or wide area mobile communication networks.</p> <p>The following topics are discussed in detail:</p> <ul style="list-style-type: none"> • technical foundation of wireless transmission • media access control protocols • resource management protocols in mobile communication networks (including resource assignment strategies at the radio layer, handoff management, error control protocols, scheduling etc.) • mobility support at the network layer by mobile IP • transport protocols and their enhancements • wireless LANs and their development (IEEE802.11 standards, WiMAX etc.) • wireless wide area networks based on TDMA technology (GSM basics and protocols, GPRS) • data communication in wireless wide area networks (UMTS, HSPA, LTE, LTE-A etc.) • service architectures for mobile networks (including Android programming and WebRTC architectures) 	
<p>Learning outcomes:</p> <p>The students are encouraged to independent scientific work. They learn the fundamentals of mobile communication and are trained to analyze the applied protocols and communication algorithms in a systematic manner. Students are instructed to investigate the sketched mobile communication protocols by measurements using Wireshark and other tools, to evaluate their performance, and to develop new protocol elements. The processing of design, programming, and performance assessment tasks by teams of students and the effective arrangement of workgroups is part of the training.</p>	
<p>Remark:</p> <p>The module can be selected by exchange students and master students speaking only English.</p>	
<p>prerequisites for the module:</p> <p>none</p>	
<p>Recommended prior knowledge:</p> <ul style="list-style-type: none"> • substantial knowledge of the foundations of data communication similar to module KTR-Datkomm-B • good knowledge of programming in JAVA (or C++) • knowledge of algorithms and data structures similar to module MI-AuD-B <p>Module Algorithms and Data Structures (AI-AuD-B) - recommended Module Advanced Java Programming (DSG-AJP-B) - recommended</p>	<p>Admission requirements:</p> <p>governed by examination regulations (StuFPO)</p>

Module Data communication (KTR-Datkomm-B) - recommended		
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units

<p>Mobile Communication Course Mode of Delivery: Lectures and Practicals Lecturers: Prof. Dr. Udo Krieger Language: English/German Frequency: every winter semester</p> <hr/> <p>Learning outcome: The students are encouraged to independent scientific work. They learn the fundamentals of mobile communication and are trained to analyze the applied protocols and communication algorithms in a systematic manner. Students are instructed to investigate the sketched mobile communication protocols by measurements using Wireshark and other tools, to evaluate their performance, and to develop new protocol elements. The processing of design, programming, and performance assessment tasks by teams of students and the effective arrangement of workgroups is part of the training.</p> <hr/> <p>Contents: The course presents the fundamentals of mobile communication. We sketch the underlying standards, system architectures and their realizations as well as current research and development trends. Due to the complexity of the field the course can only present some basic important aspects of those mobile communication systems that exhibit the strongest growth in the markets and affect all business areas of the information societies at most. The course will focus on the technical system and design perspectives regarding the service architectures and local or wide area mobile communication networks. The following topics are discussed in detail:</p> <ul style="list-style-type: none"> • technical foundation of wireless transmission • media access control protocols • resource management protocols in mobile communication networks (including resource assignment strategies at the radio layer, handoff management, error control protocols, scheduling etc.) • mobility support at the network layer by mobile IP • transport protocols and their enhancements • wireless LANs and their development (IEEE802.11 standards, WiMAX etc.) • wireless wide area networks based on TDMA technology (GSM basics and protocols, GPRS) • data communication in wireless wide area networks (UMTS, HSPA, LTE, LTE-A etc.) • service architectures for mobile networks (including Android programming and WebRTC architectures) <p>The content of the lectures is illustrated by exercises and laboratories covering important aspects of the protocol stacks in mobile networks. The independent</p>	<p>4,00 Weekly Contact Hours</p>
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processing of tasks, the qualified presentation and critical discussion of the outcomes by teams of students is part of the course. It improves the technical understanding and provides means to work as project leader in industry on those topics.

The course can be supplemented by the module Foundations of Internet

Communication (KTR-GIK-M) with its instructive tasks executed in the router laboratory, by master seminars and projects or a master's thesis on related topics in next generation networks.

The language of the course will be announced during the first lecture.

Literature:

- Schiller, J.: Mobile Communications. Pearson-Education, Munich, 2004.
- Walke, B.: Mobile Radio Networks, Wiley, 2002.
- Pahlavan, K., Krishnamurthy, P.: Principles of Wireless Networks, A Unified Approach. Prentice Hall, 2002.
- Pahlavan, K., Krishnamurthy, P.: Networking Fundamentals: Wide, Local and Personal Area Communications, Wiley, 2009.
- Holma, H., Toskala, A.: LTE for UMTS, Evolution to LTE-Advanced, 2. ed, Wiley, 2011.

Examination

Oral examination / Duration of Examination: 30 minutes

Description:

30 minutes oral examination covering all topics of the lectures and practicals.

The language of the examination will be announced during the first lecture.

<p>Module KTR-SSSProj-M KTR Master Project Software Systems Science <i>KTR Masterprojekt Software Systems Science</i></p>	<p>9 ECTS / 270 h 70 h Präsenzzeit 200 h Selbststudium</p>
<p>(since WS17/18) Person responsible for module: Prof. Dr. Udo Krieger</p>	
<p>Contents: Important skills regarding the planning, development and implementation of new communication technologies, their advanced services, and the related protocols in next generation networks can only be learnt by team oriented development projects subject to stringent time and resource constraints, and clear development objectives, similar to an industrial project environment. After a short training phase and based on an autonomous working mode, students will learn by a teamwork project to solve advanced communication tasks and to implement new communication services associated with current research issues of the professorship. Actual topics will be announced on the web page of the module.</p>	
<p>Learning outcomes: The students are encouraged to independent scientific work. They learn how to plan, develop and implement new advanced multimedia services and communication protocols in next generation networks. They are trained to efficiently implement the applied protocols and to analyze the performance of the communication algorithms in a systematic manner. Students are instructed to investigate their developed protocol code elements by measurements and other tools, to evaluate their performance, and to develop improved protocol units. The processing of design, programming, and performance assessment tasks by teams of students and the effective arrangement of the groupwork is part of the training. The project follows scientific standards and deals with research issues of the professorship. The overall objective is to develop skills and knowledge required for a successful career in industry or research in the field of communication engineering.</p>	
<p>Remark: The module can be selected by exchange students and master students speaking only English.</p>	
<p>prerequisites for the module: A bachelor degree in computer science, computer engineering or mathematics is required. Students must be enrolled in the masters degree programme "M.Sc. International Software Systems Science".</p>	
<p>Recommended prior knowledge:</p> <ul style="list-style-type: none"> • good knowledge in mathematics and statistics, similar to module Mathematik für Informatiker 2 • good programming skills in JAVA (or C++) • good knowledge in data communication, similar to module KTR-Datkomm-B • solid methodological know-how in planning and execution of software projects, similar to the module "Software Engineering Lab" (SWT-SWL-B) <p>Module Introduction to Parallel and Distributed Programming (DSG-PAKS-B) - recommended Module Data communication (KTR-Datkomm-B) - recommended</p>	<p>Admission requirements: governed by examination regulations (StuFPO)</p>

Module Mathematics for Computer Science 2 (Linear Algebra) (KTR-Mfi-2) - recommended		
Module Software Engineering Lab (SWT-SWL-B) - recommended		
Frequency: every semester	Recommended semester: 2.	Minimal Duration of the Module: 1 Semester

Module Units	
<p>KTR Master Project Software Systems Science</p> <p>Mode of Delivery:</p> <p>Lecturers: Prof. Dr. Udo Krieger</p> <p>Language: English/German</p> <p>Frequency: every semester</p> <hr/> <p>Learning outcome:</p> <p>The details are sketched previously.</p> <hr/> <p>Contents:</p> <p>Important skills regarding the planning, development and implementation of new communication technologies, their advanced services, and the related protocols in next generation networks can only be learnt by team oriented development projects subject to stringent time and resource constraints, and clear development objectives, similar to an industrial project environment. After a short training phase and based on an autonomous working mode, students will learn by a teamwork project to solve advanced communication tasks and to implement new communication services associated with current research issues of the professorship.</p> <p>The organization of the project is following the framework of industry. It comprises definition, preparation, implementation and presentation phases. An incremental processing is performed like in industrial projects. It means</p> <ul style="list-style-type: none"> • a segmentation into specific work packages, • its division into tasks and subtasks including milestones • the presentation of intermediate results • a final report with presentation and an individual colloquium to defend the outcome. <p>Research and development tasks are related to current research issues in "Future Generation Internet" and will be integrated into the module. An actual list of studied topics and related references are presented in the first lecture.</p> <p>The language of the course will be announced during the first lecture.</p> <hr/> <p>Literature:</p> <p>A reference list will be provided in the first meeting of the project.</p>	<p>6,00 Weekly Contact Hours</p>

<p>Examination</p> <p>Coursework Assignment and Colloquium / Duration of Examination: 30 minutes</p> <p>Duration of Coursework: 4 months</p> <p>prerequisites for module examination:</p> <p>Regelmäßige Teilnahme an der Lehrveranstaltung</p>	
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Description:

The course duration is one semester. The assessment of the module covers the results of the project report, written either as groupwork or on an individual basis by the student, the project presentation, and the final colloquium arranged on an individual basis.

The language of the course and its examination is announced during the first lecture.

Module KTR-Sem-M Master Seminar Communication Systems and Computer Networks <i>Hauptseminar zu Kommunikationssystemen und Rechnernetzen</i>		3 ECTS / 90 h
(since SS20) Person responsible for module: Prof. Dr. Udo Krieger		
Contents: The seminar will discuss hot topics in the fields of stationary and mobile communication networks, new Internet services as well as fog and cloud computing architectures. The development of powerful transport and edge computing platforms for future generation software-defined networks supporting quality-of-service and mobility requirements will constitute a technical focus of the seminar.		
Learning outcomes: A major competence objective is given by the ability to evaluate the scientific literature in a critical manner and to apply new scientific results while solving a technical problem at hand. We shall improve the ability to adopt effectively the new technical methodologies stemming from the fields of software-defined communication networks, the theory of distributed systems, and the foundations of computer science.		
Remark: The workload comprises the following components: <ul style="list-style-type: none"> • personal presence phases including topic dissemination and discussions with the lecturers: 20 hours • preparation of the technical topic and writing of the report: 54 hours • preparation of the oral presentation: 16 hours 		
prerequisites for the module: <ul style="list-style-type: none"> • knowledge on topics of the module Foundations of Internet Communication (KTR-GIK-M) Module Foundations of Internet Communication (KTR-GIK-M) - Pflicht		
Recommended prior knowledge: <ul style="list-style-type: none"> • basic knowledge on the principles of data communication • additional knowledge according to the technical specification of the offered seminar Module Data communication (KTR-Datkomm-B) - recommended		Admission requirements: none
Frequency: winter or summer semester, on demand	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
Seminar KTR-Master Mode of Delivery: Advanced seminar Lecturers: Prof. Dr. Udo Krieger Language: English/German Frequency: winter and summer semester, on demand	2,00 Weekly Contact Hours
Learning outcome: The students will prepare the writing of a master's thesis and their industrial or scientific employment. A major competence objective is given by the ability to evaluate the scientific literature in a critical manner and to apply new scientific results while solving a technical problem at hand.	

Contents:

The seminar will discuss hot topics in the fields of stationary and mobile communication networks, new Internet services as well as fog and cloud computing architectures. The development of powerful transport and edge computing platforms for future generation software-defined networks supporting quality-of-service and mobility requirements will constitute the technical focus of the seminar.

The seminar offers a student the perspectives on the system-theoretical foundations of actual technical topics arising in the rapidly evolving areas of modern communication and fog/cloud computing systems. It is the objective of study to independently adopt the new technical methodologies stemming from the fields of software-defined communication networks, the theory of distributed systems, and the foundations of computer science.

Passing the examination of the seminar is, in general, a prerequisite to successfully write a master's thesis at the Professorship of Computer Science or in cooperation with industrial peers.

The used language of the module will be announced during the first session of the seminar.

Literature:

The relevant reference list will be announced during the first session.

Examination

Coursework Assignment with presentation / Duration of Examination: 40 minutes

Duration of Coursework: 4 months

prerequisites for module examination:

Regelmäßige Teilnahme an der Lehrveranstaltung

Description:

The final grade evaluates the written report (- this phase lasts at most 4 months -) and the oral presentation as equally weighted components. Both the report and oral presentation have to achieved at least the grade 4.0 to pass the examination.

The language of the examination will be announced during the first session of the seminar.

Module KogSys-ML-M Machine Learning <i>Lernende Systeme (Machine Learning)</i>		6 ECTS / 180 h
(since SS20) Person responsible for module: Prof. Dr. Ute Schmid		
Contents: In this course advanced concepts and methods of machine learning are introduced in the context of symbolic, neuronal, and statistical algorithms.		
Learning outcomes: Students will be able to: <ul style="list-style-type: none"> • name research goals of machine learning • name and explain research questions of machine learning • name and explain basic concepts of classification learning • name symbolic, neuronal, and statistic algorithms of classification learning and apply them on given data • evaluate the fitness of algorithms for classification learning on given data • name, explain, and apply special procedures of machine learning • name and explain basic concepts of human learning • discuss connections between human learning and machine learning 		
Remark: The default language of instruction in this course is German. However, the lectures and/or tutorials may be delivered in English if there are participating students who prefer English over German. Most course materials (lecture slides and tutorial notes) are available in English. The workload can roughly be split as follows: 22.5 h lecture sessions + 30 h follow-up over 15 weeks 22.5 h practice sessions + 75 h practice over 15 weeks 30 h exam preparation		
prerequisites for the module: none		
Recommended prior knowledge: Module Mathematics for Computer Scientists 1 (propositional- and first-order logic) (GdI-Mfl-1) Module Algorithms and Data Structures (MI-AuD-B)		Admission requirements: none
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module: 1 Semester
Module Units		
1. Lectures Machine Learning Mode of Delivery: Lectures Lecturers: Prof. Dr. Ute Schmid Language: German/English Frequency: every winter semester		2,00 Weekly Contact Hours
Learning outcome: see above		

<p>Contents: In this course well-known symbolical, statistical, and neuronal approaches of machine learning are introduced in details and relations to human learning are discussed. Core topics are: decision tree algorithms, multi-layer perceptrons, instance-based learning, inductive logic programming, genetic algorithms, Bayesian learning, kernel methods, Support Vector Machines, inductive program synthesis, and reinforcement learning. The language of this course is announced in the first lecture.</p> <p>Literature: Mitchell, Machine Learning</p>	
<p>2. Practices Machine Learning Mode of Delivery: Practicals Lecturers: Scientific Staff Angewandte Informatik, insb. Kognitive Systeme Language: German/English Frequency: every winter semester</p> <hr/> <p>Learning outcome: see above</p> <hr/> <p>Contents: Deepening of methods and techniques from the lecture partly with programming tasks and applications in RapidMiner.</p> <hr/> <p>Literature: see lecture</p>	<p>2,00 Weekly Contact Hours</p>
<p>Examination Written examination / Duration of Examination: 90 minutes</p> <p>Description: In the exam 90 points can be reached. The exam is passed if 40 percent are reached. In addition to the duration of the test, a reading time of 15 minutes is granted to select the tasks to work on from the pool of possible tasks. During the semester exercise sheets will be handed out. For their voluntary processing one or two weeks are available. The solutions of exercise sheets will be evaluated. If the exam is passed the evaluation of the exercise sheets will be taken into account for the calculation of the grade. It is possible to reach a 1.0 without points of the exercise sheets. Legal aids: Hand written and printed materials, a calculator without alphanumeric keypad and graphic display. The language of this exam is announced in the first lecture.</p>	

Module KogSys-Sem-M2 Reading Club Cognitive Systems		3 ECTS / 90 h
<i>Reading Club Kognitive Systeme</i>		
(since WS20/21)		
Person responsible for module: Prof. Dr. Ute Schmid		
Contents:		
In the seminar, course focus is on in-depth familiarisation with a specific topic from machine learning based on knowledge and skills acquired in the machine learning module offered by the Cognitive Systems Group. The seminar topics are focussing on a specific research domain within machine learning, for example: deep learning approaches, inductive logic programming, statistical relational learning, learning for autonomous agents		
Learning outcomes:		
<ul style="list-style-type: none"> – Independent, in-depth familiarization with a specific research approach from the domain of machine learning based on scientific literature with a focus on a specific algorithm or method – Independent search for scientific literature and assessment of its quality and relevance – Oral presentation of a scientific paper – Writing a research paper in English focussing on a specific research question following a specified format – Hands-on exploration of the selected algorithm or method – Discussion of research papers with peers 		
Remark:		
The default language in this course is German. However, the sessions can be in English if there are participating students who prefer English over German. Background material (e.g. research papers, handbooks) for this course is available in English.		
The written reports/seminar essay and the presentation may be delivered in English or in German.		
prerequisites for the module:		
none		
Recommended prior knowledge:		Admission requirements:
Successful participation at the module Machine Learning or a comparable module		None
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module:
		1 Semester
Module Units		
Seminar Reading Club Kognitive Systeme		2,00 Weekly Contact Hours
Mode of Delivery: Seminar, Key competence		
Lecturers: Johannes Rabold		
Language: German/English		
Frequency: every summer semester		
Contents:		

<p>In the seminar, selected aspects of Machine Learning or Inductive Programming will be worked on in-depth and presented in oral presentations as well as a written paper. The teaching language will be announced in the first lecture.</p>	
<p>Literature: Will be announced at the beginning of the seminar</p>	
<p>Examination Coursework Assignment with presentation / Duration of Examination: 30 minutes Duration of Coursework: 4 months</p> <p>Description: Written report on the topic dealt with in the seminar. The examination language will be announced in the first meeting. The workload for this module is roughly structured as follows: 22.5 h presence in the course sessions 2.5 h individual discussion meetings with the lecturer 30 h study of of literature (incl. algorithms, systems) 10 h preparation of presentation 25 h writing of the report</p>	

Module MOBI-ADM-M Advanced Data Management <i>Advanced Data Management</i>		6 ECTS / 180 h 45 h Präsenzzeit 135 h Selbststudium
(since SS20 to SS20) Person responsible for module: Prof. Dr. Daniela Nicklas		
Contents: With the rapid growth of the internet and more and more observable processes, many data sets became so large that they cannot be processed with traditional database methods any more. This modul covers advanced data management and integration techniques (also known under the term "big data") that are useful when dealing with very large data sets.		
Learning outcomes: The students will understand the challenges of big data, and will be able to apply some of the new techniques to deal with it.		
Remark: The main language of instruction in this course is English. However, the lectures and/or tutorials may be delivered in German if all participating students are fluent in German. The written reports/seminar essay and the presentation may be delivered in English or in German.		
prerequisites for the module: none		
Recommended prior knowledge: Foundations of relational databases, relational algebra and SQL; e.g. from Modul SEDA-DMS-B: Data management systems		Admission requirements: none
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
1. Lectures Advanced Data Management Mode of Delivery: Lectures Lecturers: Prof. Dr. Daniela Nicklas Language: English Frequency: every summer semester <hr/> Contents: The lecture will cover various algorithms for clustering, association rule mining, or page ranking and their scalable processing using map and reduce methods, data integration, data cleansing and entity recognition. The exercises will be built upon the Hadoop framework. The language of the course will be announced in the first lecture. <hr/> Literature: L. Wiese, Advanced Data Management, For SQL, NoSQL, Cloud and Distributed Databases. Berlin, Boston: De Gruyter, 2015	2,00 Weekly Contact Hours
2. Practicals Advanced Data Management Mode of Delivery: Practicals Lecturers: Prof. Dr. Daniela Nicklas	2,00 Weekly Contact Hours

<p>Language: English</p> <p>Frequency: every summer semester</p> <hr/> <p>Contents: see Lectures</p> <p>The language of the course will be announced in the first lecture.</p>	
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<p>Examination Written examination / Duration of Examination: 60 minutes</p> <p>Description: central written exam.</p> <p>The examination language is English.</p>	
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Module MOBI-DSC-M Data Streams and Complex Event Processing <i>Data Streams and Complex Event Processing</i>		6 ECTS / 180 h 45 h Präsenzzeit 135 h Selbststudium
(since WS19/20 to SS20) Person responsible for module: Prof. Dr. Daniela Nicklas		
Contents: The management of data streams and foundations of event processing: Applications, systems, query languages, continuous query processing, and security in distributed data stream management systems. The modul covers the following topics: Architectures of data stream management systems; Query languages; Data stream processing; Complex event processing; Security in data stream management systems; Application of data stream management systems		
Learning outcomes: Understand the challenges of data stream management and complex event processing Recognize and link basic building blocks of data stream management tasks in different frameworks and systems Develop and program queries on data streams and event streams in different query languages to process data streams and detect event patterns Understand basic implementation techniques for data stream operators Understand the main security challenges and solutions in data stream management systems		
prerequisites for the module: none		
Recommended prior knowledge: Foundations of relational databases, relational algebra and SQL; e.g. from Modul MOBI-DBS-B: Database Systems		Admission requirements: none
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
Data Streams and Complex Event Processing Mode of Delivery: Lectures Lecturers: Prof. Dr. Daniela Nicklas Language: English Frequency: every winter semester	2,00 Weekly Contact Hours
Learning outcome: Understand the challenges of data stream management and complex event processing Recognize and link basic building blocks of data stream management tasks in different frameworks and systems Develop and program queries on data streams and event streams in different query languages to process data streams and detect event patterns Understand basic implementation techniques for data stream operators	

<p>Understand the main security challenges and solutions in data stream management systems</p>	
<p>Contents: The management of data streams and foundations of event processing: Applications, systems, query languages, continuous query processing, and security in distributed data stream management systems. The modul covers the following topics: Architectures of data stream management systems; Query languages; Data stream processing; Complex event processing; Security in data stream management systems; Application of data stream management systems</p>	
<p>Examination Oral examination / Duration of Examination: 15 minutes Description: oral or written exam (will be announced in class at the beginning of the semester). The examination language is English.</p>	

<p>Module Units</p>	
<p>Data Streams and Complex Event Processing Mode of Delivery: Practicals Language: English Frequency: every winter semester</p>	<p>2,00 Weekly Contact Hours</p>
<p>Contents: see lecture</p>	

<p>Examination Written examination / Duration of Examination: 60 minutes Description: oral or written exam (will be announced in class at the beginning of the semester). The examination language is English.</p>	
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Module MOBI-PRS-M Master Project Mobile Software Systems (SoSySc)		9 ECTS / 270 h
<i>Master Project Mobile Software Systems (SoSySc)</i>		
(since WS20/21)		
Person responsible for module: Prof. Dr. Daniela Nicklas		
Contents:		
<p>Applications of in mobile software systems, which are taken from current research activities in mobile, context-aware systems and data stream management, are carried out in part individually and in part in small teams of students, from conception, via theoretical and/or practical realization, to evaluation. In particular, the project concerns the development of sound concepts pertaining to the task to be addressed under the given project constraints. This requires studying the current research literature and relevant approaches on the project's topic.</p> <p>An example of a project task would be the conceptual development, the prototypic implementation, and the case-study-driven evaluation of a small sensor-based, mobile system, which would require knowledge from the modul MOBI-DSC-M Data streams and event processing.</p> <p>The tasks in the project will be tailored to Master level.</p>		
Learning outcomes:		
Students will deepen their knowledge regarding the conceptual problems that arise when carrying out theoretical and/or practical research and software projects, and regarding approaches to possible solutions. Since this will be done by means of the intensive conduct of a research topic in Mobile Software Systems, students will gain important experience in carrying out research-oriented projects, from project planning, to the abstract and concrete design, to the realization, to the documentation of results in a scientific project report.		
Remark:		
The main language of instruction in this course is English. However, the lectures and/or tutorials may be delivered in German if all participating students are fluent in German.		
The written reports/seminar essay and the presentation may be delivered in English or in German.		
prerequisites for the module:		
none		
Recommended prior knowledge:		Admission requirements:
Basic programming skills (Java or Python); scientific writing skills, e.g., obtained from the course SSS-SRW-M or from a scientific Bachelor thesis; basic knowledge in Mobile Computing as offered, e.g., by the course MOBI-MSS-B. Dependent on the topic of the specific project, additional knowledge as discussed in the courses MOBI-DSC-M or MOBI-ADM-M can be required.		none
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester
Module Units		
Master Project Mobile Software Systems (SoSySc)		6,00 Weekly Contact Hours
Mode of Delivery: Practicals		
Lecturers: Prof. Dr. Daniela Nicklas		

<p>Language: English/German Frequency: every summer semester</p> <hr/> <p>Contents: Conduct of the project, accompanied by regular meetings between students and lecturer. The language of the course will be announced in the first lecture.</p>	
<p>Examination Coursework Assignment and Colloquium prerequisites for module examination: Regelmäßige Teilnahme an der Lehrveranstaltung</p> <p>Description: Als Prüfungsleistung ist eine Hausarbeit sowie ein Kolloquium zu erbringen. Die Bearbeitungsfrist der Hausarbeit und die Prüfungsdauer des Kolloquiums werden zu Beginn einer jeden Lehrveranstaltung von der Projektleiterin bzw. dem Projektleiter bekannt gegeben. Production of a written report on the software project carried out (Assignment/Hausarbeit). Discussion of this project report and of the developed artefacts in the context of the wider project topic (Colloquium/Kolloquium). The term of the project report and of the colloquium will be announced at the beginning of each course by the project leader.</p>	

Module MOBI-SEM-M Master-Seminar Mobile Software Systems		3 ECTS / 90 h
<i>Master-Seminar Mobile Software Systems</i>		
(since WS17/18)		
Person responsible for module: Prof. Dr. Daniela Nicklas		
Contents: Sensors continuously supply data that often cannot be understood by machines in its raw form. The topics in this seminar deal with different processes of how to obtain better information from continuous (sensor) data streams.		
Learning outcomes: gaining professional competence regarding the critical and systematic analysis of scientific literature; learning techniques to structure complex facts in the field of software systems science in systematic manner; evaluation of competing approaches; learning techniques to present scientific topics in professional manner and to write scientific papers.		
Remark: The module covers independent study and presentation of a topic on the chosen subject area, using scientific methods. Details on the topic and literature will be will be announced by the lecturer offering this module a the beginning of the seminar. The seminar thesis and the presentation may be delivered in English or in German		
prerequisites for the module: none		
Recommended prior knowledge: Scientific research and writing, e.g. from the module "IAIWAI-B Wissenschaftliches Arbeiten" or "SSS-SRW-M Scientific Research on Writing for Master´s Students".		Admission requirements: none
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module: 1 Semester
Module Units		
Mobile Software Systems Mode of Delivery: Seminar Lecturers: Prof. Dr. Daniela Nicklas Language: English Frequency: every winter semester		2,00 Weekly Contact Hours
Contents: The language of the course will be announced in the first course.		
Examination Coursework Assignment with presentation Description: The language of the exam will be announced in the first course.		

Module PSI-AdvaSP-M Advanced Security and Privacy <i>Advanced Security and Privacy</i>	6 ECTS / 180 h 45 h Präsenzzeit 135 h Selbststudium
(since SS18 to SS20) Person responsible for module: Prof. Dr. Dominik Herrmann	
<p>Contents:</p> <p>Information security and privacy are relevant in almost all information systems today. Many real-world use cases have complex security and privacy requirements involving multiple parties. Often there are multiple stakeholders with different, sometimes even contradictory interests. For instance, some use cases call for a solution that allows a service provider to process sensitive data without learning its content. In other cases it is not the content but some meta information such as location and usage intensity that has to be protected. And then there are scenarios where seemingly harmless pieces of data can be used to disclose or infer very personal pieces of information about an individual.</p> <p>This module covers advanced techniques for information security and privacy that can be used to satisfy the complex requirements of practical systems. It builds upon the basic concepts in information security that are introduced in the module "Introduction to Security and Privacy" (PSI-IntroSP-B).</p>	
<p>Learning outcomes:</p> <p>This module is designed to bring students towards the research boundaries in the field of security and privacy technologies by covering a selection of contemporary topics in depth. The focus of the module is on technical safeguards that can be used by system designers and users to enforce properties such as confidentiality and integrity. Moreover, sophisticated attacks on security and privacy are explained.</p> <p>Successful students will be able to explain attack strategies and defenses discussed in recent research papers. They will also be able to analyze whether a particular attack or defense is relevant in a specific scenario. Finally, they will be able to implement selected attacks and defenses with a programming language of their choice.</p>	
<p>Remark:</p> <p>This module is taught in English. It consists of a lecture and tutorials. During the course of the tutorials there will be theoretical and practical assignments (task sheets). Assignments and exam questions can be answered in English or German.</p> <p>Lecture and tutorials are partially taught in form of a paper reading class. Participants are expected to read the provided literature in advance and participate in the discussions.</p> <p>Workload breakdown:</p> <ul style="list-style-type: none"> • Lecture: 22.5 hours (2 hours per week) • Tutorials: 22.5 hours (2 hours per week) • Preparation and studying during the semester: 30 hours • Assignments: 67.5 hours • Preparation for the exam (including the exam itself): 37.5 hours 	
<p>prerequisites for the module: none</p>	
<p>Recommended prior knowledge: Participants should be familiar with basic concepts in information security and privacy, which can be acquired, for instance, by taking the module "Introduction to Security and Privacy" (PSI-IntroSP-B).</p>	<p>Admission requirements: none</p>

This includes basic knowledge about the commonly used security terminology, common types of malware and attacks, buffer overflows and related attacks, cryptography, network security, web security, and concepts of privacy. Moreover, participants should have practical experience with at least one scripting or programming language such as Python or Java.		
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
<p>1. Advanced Security and Privacy Mode of Delivery: Lectures Language: English/German Frequency: every summer semester</p> <hr/> <p>Learning outcome: cf. module description</p> <hr/> <p>Contents: Selected topics:</p> <ul style="list-style-type: none"> • Cryptographic methods and protocols, e.g., homomorphic encryption, attribute-based credentials, secure multi-party computation, zero-knowledge proofs, format-preserving and identity-based encryption, group signatures, and proxy re-encryption. • Attacks on privacy in datasets and communications (inference techniques, online tracking) • Privacy engineering and privacy enhancing technologies (e.g., Tor) • Usable security and privacy • Other current topics in privacy and security <p>Some parts of the lecture are aligned with current events and recently published research. The selected topics are therefore subject to change.</p> <hr/> <p>Literature: Selected books:</p> <ul style="list-style-type: none"> • R. Anderson: Security Engineering • A. Shostack: Threat Modelling • J.-P. Aumasson: Serious Cryptography • W. Stallings: Computer Security: Principles and Practice • B. Schneier et al.: Cryptography Engineering • J. Erickson: Hacking: The Art of Exploitation • J. Katz & Y. Lindell: Introduction to Modern Cryptography • L. Cranor & S. Garfinkel: Security and Usability 	2,00 Weekly Contact Hours
<p>2. Tutorials for Advanced Security and Privacy Mode of Delivery: Practicals Language: English/German Frequency: every summer semester</p>	2,00 Weekly Contact Hours

Examination

Written examination / Duration of Examination: 90 minutes

Description:

The content that is relevant for the exam consists of the content presented in the lecture and tutorials (including the assignments) as well as the content of the discussed papers. The maximum number of points that can be achieved in the exam is 100.

Participants that solve all assignments correctly can collect up to 20 bonus points. Details regarding the number of assignments, the number of points per assignment, and the type of assignments will be announced in the first lecture. If the points achieved in the exam are sufficient to pass the exam on its own (generally, this is the case when at least 50 points have been obtained), the bonus points will be added to the points achieved in the exam. The grade 1.0 can be achieved without the bonus points.

Module PSI-ProjectCAD-M Project Complex Attacks and Defenses <i>Project Complex Attacks and Defenses</i>	9 ECTS / 270 h
(since SS18) Person responsible for module: Prof. Dr. Dominik Herrmann	
<p>Contents:</p> <p>Breaking into information systems is exciting, but impractical due to ethical and legal concerns. However, offensive competences and adversarial thinking are essential to build secure systems. In this project students will get the opportunity to acquire practical security skills in a dedicated training environment.</p> <p>The goal of this project is to build and extend the "Insekta" platform. This web-based tool provides a frontend for virtual machines that can be used to study selected topics in security and privacy on one's own and at one's own pace.</p> <p>This project is offered together with PSI-ProjectPAD, which focuses on conceptually simpler attacks and defenses.</p> <p>The participants of the project familiarize themselves with security weaknesses in information systems and apply this knowledge to develop vulnerable services which others can use for training. To this end, participants form groups, read about attacks and defenses in textbooks and research papers, and discuss various options to implement them. Instructors will provide extensive and on-demand support to enable the participants to implement a vulnerable service that can be exploited to learn about a particular vulnerability.</p> <p>Besides implementing vulnerable services, the participants prepare training materials, which consist of questions and tasks to test one's knowledge as well as step-by-step instructions. These training materials may also contain interactive elements for an improved learning experience.</p> <p>The project also takes into account attacks on privacy, e.g., re-identifying individuals in anonymized datasets and communication networks, tracking users on the Internet, inferring sensitive attributes from seemingly harmless data traces, as well as mitigations, e.g., depersonalization strategies and differential privacy mechanisms. Here, practical activities consist in the preparation of datasets and scripts for analysis.</p>	
<p>Learning outcomes:</p> <p>Successful students will be able to describe attacks and defenses from textbooks and research papers in easily understandable form. They will also be able to carry out selected attacks in practice and implement defenses with a programming language of their choice.</p>	
<p>Remark:</p> <p>This project is taught in English, unless all participants are fluent in German. The workload of this project is equivalent to 270 hours.</p> <p>Workload breakdown:</p> <ul style="list-style-type: none"> • 20 hrs: Getting familiar with the platform • 50 hrs: Reading papers and researching security vulnerabilities • 20 hrs: Preparing the talk (including time for attendance of other talks) • 90 hrs: Implementing the vulnerable service and defenses • 90 hrs: Writing training material and documentation <p>Note that there is another project (PSI-ProjectPAD) with a workload equivalent to 180 hours.</p>	

prerequisites for the module: none		
Recommended prior knowledge: This project is primarily intended for students in master programs. Students in bachelor programs can participate, if they are qualified. Participants should be familiar with basic concepts in information security and privacy, which can be acquired, for instance, by taking the module "Introduction to Security and Privacy" (PSI-IntroSP-B). This includes basic knowledge about the commonly used security terminology, common types of malware and attacks, buffer overflows and related attacks, cryptography, network security, web security, and concepts of privacy. Moreover, participants should have practical experience with at least one scripting or programming language such as Python or Java. Experience with Linux environments, web technologies, and network protocols is recommended.		Admission requirements: none
Frequency: every semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
Project Complex Attacks and Defenses Mode of Delivery: Practicals Language: English/German Frequency: every semester <hr/> Learning outcome: cf. module description <hr/> Contents: Potential topics include: <ul style="list-style-type: none"> • web security (injection flaws and other issues mentioned in the OWASP Top 10) • network security (such as DNS cache poisoning and rebinding attacks) • security issues in C programs (buffer overflows, etc.) • cryptography (low-level attacks on ciphers, high-level attacks on protocols, e.g., TLS) • business logic failures • misconfigurations • attacks on availability (denial of service) • attacks on privacy (such as inference, tracking, re-identification, fingerprinting) • privacy defenses (such as k-anonymity, related concepts, differential privacy) <hr/> Literature: Literature will be announced at the beginning of the project.	6,00 Weekly Contact Hours

Examination

Coursework Assignment and Colloquium / Duration of Examination: 30 minutes

Duration of Coursework: 3 months

prerequisites for module examination:

Regular attendance at project meetings.

Description:

The module examination consists of two parts: Firstly, the participants submit a written report (in English) that includes the source code of the vulnerable service and the training material. Secondly, the participants give a talk in which they defend their work (in English; in German if all participants are fluent in German) by presenting theoretical and practical aspects of their vulnerable service as well as relevant mitigations. The maximum number of points that can be achieved in the module examination is 100.

Optionally, participants can submit intermediary results (in English) to collect up to 20 bonus points. If the module examination is passed on its own (generally, this is the case when at least 50 points are obtained), the bonus points will be added to the points achieved in the module examination. The grade 1.0 can be achieved without the bonus points. Details regarding the number of optional submissions during the semester, their type, the points per submission, and the respective deadlines will be announced in the first session of the project.

Module PSI-ProjectSP-M Project Security and Privacy		9 ECTS / 270 h
<i>Project Security and Privacy</i>		
(since SS18)		
Person responsible for module: Prof. Dr. Dominik Herrmann		
Contents:		
In this project participants work independently on problems related to current research activities of the Privacy and Security in Information Systems Group. Instructors will provide guidance and supervision.		
Learning outcomes:		
Successful students will be able to independently work on research problems in security and privacy. They will also be able to implement tools and/or analyze data in order to answer a research question. Finally, they will be able to present their work in a talk and document their approach and results in a written report.		
Remark:		
This project is taught in English unless all participants are fluent in German. The workload of this project is equivalent to 270 hours.		
Workload breakdown:		
<ul style="list-style-type: none"> • 60 hrs: Getting familiar with the problem and preliminaries: reading related work, and understanding potentially existing source code • 20 hrs: Preparing the talk (including time for attendance of other talks) • 110 hrs: Implementing tools and/or analyzing data • 80 hrs: Writing final report with approach and methods 		
prerequisites for the module:		
none		
Recommended prior knowledge:		Admission requirements:
Participants should have advanced knowledge and practical skills in information security and privacy, which can be acquired, for instance, in the module PSI-IntroSP-B and a security-related seminar or project. Depending on the actual topic participants may be expected to be familiar with commonly used security terminology, common types of malware and attacks, buffer overflows and related attacks, cryptography, network security, web security, and concepts of privacy.		none
Moreover, participants should have practical experience with at least one scripting or programming language such as Python or Java. Alternatively, participants should have strong skills in empirical data collection and data analytics (statistics and/or machine learning).		
Experience with Linux environments, web technologies, and network protocols is recommended.		
Frequency: every semester	Recommended semester:	Minimal Duration of the Module:
		1 Semester
Module Units		
Project Security and Privacy		6,00 Weekly Contact Hours
Mode of Delivery: Practicals		
Language: English/German		

Frequency: every semester

Learning outcome:

cf. module description

Contents:

Potential topics include

- empirical studies, either manually (surveying security properties of systems) or automatically (e.g., web crawls),
- creating scanning tools and platforms where results can be published in a meaningful way (e.g., PrivacyScore.org),
- analyzing data sets for aspects of security and privacy, and
- implementing cryptographic or anonymization techniques in a secure fashion, e.g., for encrypted storage in cloud services.

Literature:

Literature will be announced at the beginning of the project.

Examination

Coursework Assignment and Colloquium / Duration of Examination: 30 minutes

Duration of Coursework: 3 months

prerequisites for module examination:

Regular attendance at project meetings.

Description:

The module examination consists of two parts: Firstly, the participants submit a written report (in English) that includes the source code, datasets, and analysis scripts. Secondly, the participants give a talk in which they defend their work (in English; in German if all participants are fluent in German) by presenting related work, their approach, and results. The maximum number of points that can be achieved in the module examination is 100.

Optionally, participants can submit intermediary results (in English) to collect up to 20 bonus points. If the module examination is passed on its own (generally, this is the case when at least 50 points are obtained), the bonus points will be added to the points achieved in the module examination. The grade 1.0 can be achieved without the bonus points. Details regarding the number of optional submissions during the semester, their type, the points per submission, and the respective deadlines will be announced in the first session of the project.

Module PSI-Sem-M Seminar Research Topics in Security and Privacy		3 ECTS / 90 h
<i>Seminar Research Topics in Security and Privacy</i>		
(since SS20)		
Person responsible for module: Prof. Dr. Dominik Herrmann		
Contents:		
This seminar provides in-depth coverage of advanced topics in one of the fields of information security and privacy.		
Participants learn to review, analyze, and discuss scientific sources (books and essays). While participants are expected to perform the actual research independently and mostly on their own, the instructors provide extensive support throughout the seminar. The instructors will provide guidance on scientific methods, e.g., how to approach a topic, how to find relevant literature, how to read a paper efficiently, how to write a seminar report, and how to give a good talk.		
Participants will be asked to deliver manageable chunks of work throughout the semester (such as summarizing literature in a survey, reviewing the work of others, writing a draft of the term paper, reviewing the draft of other students, etc.). They will receive feedback by their peers and by the instructors.		
The actual topics are subject to change. A list of available topics is made available before the first session via UnivIS or VC.		
Learning outcomes:		
The participants learn to find, read, and summarize scientific texts. They also learn to assess statements and to discuss them critically. Finally, they learn to write scientific texts and to present their results in a talk.		
Students who participate in the optional peer review process will also learn techniques to give useful feedback to others as well as how to accept feedback for one's own work.		
Remark:		
The default language in this seminar is English, unless all participants are fluent in German.		
prerequisites for the module:		
none		
Recommended prior knowledge:		Admission requirements:
Participants should have basic knowledge in software engineering, foundations of computing, operating systems, and networks. Knowledge in information security and privacy (obtained, e.g., in PSI-IntroSP-B and by having completed a seminar or thesis in the field of information security) is strongly recommended.		none
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module:
		1 Semester
Module Units		
Seminar Research Topics in Security and Privacy		2,00 Weekly Contact Hours
Mode of Delivery: Seminar		
Language: English/German		
Frequency: every winter semester		
Contents:		

cf. module description

Literature:

- Alley: The Craft of Scientific Writing
- Anderson: Security Engineering
- Pfleeger et al.: Security in Computing
- Stallings & Brown: Computer Security: Principles and Practice
- Strunk & White: The Elements of Style

Other relevant literature is presented in the first session.

Examination

Coursework Assignment with presentation / Duration of Examination: 30 minutes

Duration of Coursework: 3 months

prerequisites for module examination:

Continuous attendance in the seminar sessions is mandatory, cf. §9 (10) APO.

Description:

The module examination consists of two parts, a term paper (in English) and a talk (in English; in German if all participants are fluent in German). The maximum number of points that can be achieved in the module examination is 100. Details regarding the number of points that can be achieved in the talk and in the report will be announced in the first session of the project.

Optionally, participants can submit intermediary results (in English) such as surveys, written reviews for the work of other participants, and a draft of the term paper. Participants can thereby earn 20 bonus points. If the module examination is passed on its own (generally, this is the case when at least 50 points are obtained), the bonus points will be added to the points achieved in the module examination. The grade 1.0 can be achieved without the bonus points.

Module SME-STE-M Introduction to Knowledge Representation: Space, Time, Events		6 ECTS / 180 h
<i>Introduction to Knowledge Representation: Space, Time, Events</i>		
(since WS17/18)		
Person responsible for module: Prof. Dr. Diedrich Wolter		
Contents:		
This course gives an introduction to the area of knowledge representation, a sub-discipline of computer science in general and artificial intelligence in particular.		
Knowledge representation is involved with identifying means to represent practical problems and according background knowledge as data structures, and to develop reasoning algorithms to solve these problems.		
This course puts a spotlight on symbolic techniques to represent knowledge involving a spatio-temporal component as is typical for many practical real-world problems.		
Contents:		
<ul style="list-style-type: none"> • fundamental concepts: knowledge, abstractions, relations, logics • syntax and semantics, formalization of knowledge • representation and reasoning • qualitative algebras and constraint calculi • constraint-based reasoning • spatial logics • complexity and tractable subclasses 		
Learning outcomes:		
<ul style="list-style-type: none"> • gain overview of formalisms for representing spatio-temporal logics • gain skills to represent spatio-temporal knowledge symbolically • gain overview of reasoning problems and learn to identify approaches for solving them • learn to apply constraint-based reasoning methods • learn to identify computational complexity of reasoning problems 		
Remark:		
The main language of instruction in this course is English. Exams may be taken in either English or German. The lectures and tutorials may be delivered in German if all participating students are fluent in German.		
prerequisites for the module:		
none		
Recommended prior knowledge:		Admission requirements:
Basic knowledge in computer science is recommended, for example obtained in a computer science bachelor's curriculum.		none
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module:
		1 Semester
Module Units		
1. Lectures Introduction to Knowledge Representation: Space, Time, Events		2,00 Weekly Contact Hours
Mode of Delivery: Lectures		
Lecturers: Prof. Dr. Diedrich Wolter		

<p>Language: English/German Frequency: every winter semester</p> <hr/> <p>Learning outcome: see description of module</p> <hr/> <p>Contents: see description of module</p> <hr/> <p>Literature: will be announced in first lecture</p>	
<p>2. Practicals Introduction to Knowledge Representation: Space, Time, Events</p> <p>Mode of Delivery: Practicals Lecturers: Prof. Dr. Diedrich Wolter Language: German Frequency: every winter semester</p> <hr/> <p>Contents: practical exercises according to the lecture</p>	<p>2,00 Weekly Contact Hours</p>
<p>Examination Oral examination / Duration of Examination: 20 minutes</p> <p>Description: oral examination 20 minutes about lectures and practicals</p>	

Module SNA-OSN-M Project Online Social Networks <i>Projekt zu Online Social Networks</i>		6 ECTS / 180 h
(since WS13/14) Person responsible for module: Prof. Dr. Kai Fischbach further responsible : Zylka, Matthäus, Dipl.-Wirt.-Inf.		
Contents: This module is an introduction to the analysis of online social networks. The aim is twofold: to provide students with the tools necessary to undertake research into online networks, and to give an overview of the type of questions these data can answer.		
Learning outcomes: At the conclusion of the course, students should know not only how to calculate basic network metrics on pre-existing data sets, but also how to capture an online social network efficiently with the intent of answering a specific research question. Further goals: <ul style="list-style-type: none"> • Learn how the radical innovation process in small teams works • Learn how to collaborate in multidisciplinary intercultural virtual teams • Learn how to find trendsetter and trends on the Internet and social media • Learn how to predict trends using SNA und statistical forecasting techniques 		
Remark: The main language of instruction in this course is English. The written reports/seminar essay and the presentation have to be delivered in English.		
prerequisites for the module: none		
Recommended prior knowledge: We recommend attending at least one of the following courses: <ul style="list-style-type: none"> • Social Network Analysis (SNA-ASN-M) • Theories of Social Networks (SNA-NET-M) 		Admission requirements: keine
Frequency: every winter semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units

Online Social Networks Mode of Delivery: Practicals Lecturers: Prof. Dr. Kai Fischbach Language: English/German Frequency: every winter semester	4,00 Weekly Contact Hours
Contents: The course will define online networks, examine how they differ from offline social networks, and consider theoretical and methodological issues associated with their analysis. The sessions will explore different strategies to retrieve and analyze online network data, and present different empirical scenarios to which those tools have been applied.	
Literature:	

- Gloor, P. A. Swarm Creativity, Competitive Advantage Through Collaborative Innovation Networks. Oxford University Press, 2006

Further literature will be announced in the lecture.

Examination

Coursework Assignment and Colloquium / Duration of Examination: 30 minutes

Duration of Coursework: 4 months

prerequisites for module examination:

Regelmäßige Teilnahme an der Lehrveranstaltung

Description:

Die Gewichtung der Prüfungsleistungen Hausarbeit und Kolloquium wird zu Beginn der Lehrveranstaltung von der Dozentin bzw. dem Dozenten bekannt gegeben.

Module SSS-PraktIntKon-M Internship in an International Context		12 ECTS / 360 h
<i>Praktikum im International Kontext</i>		
(since WS19/20)		
Person responsible for module: Prof. Ph.D. Michael Mendler		
Contents: As an internship in an international context, a subject-specific internship geared to the professional field of Software Systems Science must be proven, which must be completed in an international context, preferably abroad. The internship can be completed in a foreign or internationally operating domestic company (or research institution) in private or public hands. An internship placement must be chosen in such a way that it meets the training objectives of § 39 Para. 1.		
Learning outcomes: <ul style="list-style-type: none"> • Gain work experience in an international context, for international students specifically in the German labour market • Transfer and application of the (theoretical) knowledge learned at the university in the industrial practice • Reflection on one's own strengths and weaknesses by taking responsibility for small projects, to boost confidence in one's abilities, to improve social skills • To learn to communicate constructively in a team, to create technical solutions in a partially specified context, under time and resource constraints • Networking with potential employers 		
Remark: Proof of the internship must be provided in the form of an internship certificate from the organizational unit where the internship was completed and a written internship report. The internship certificate and the internship report must be submitted together to the module manager.		
prerequisites for the module: none		
Recommended prior knowledge: none		Admission requirements: none
Frequency: every semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Examination Praktikumsbericht, unbenotet	
Description: at least 4 pages	

Module SSS-Thesis-M Master's Thesis in Software Systems Science		30 ECTS / 900 h
<i>Master Thesis in Software Systems Science</i>		
(since SS19)		
Person responsible for module: Prof. Ph.D. Michael Mendler further responsible : Professors of Computer Science		
Contents: The module for the master's thesis comprises 30 ECTS credit points and is assessed through a written exam in the form of a master's thesis document and an oral exam conducted as a colloquium. The topic of the master's thesis must be taken from one of the research areas specified in Appendix 2a of the study an examination regulations. Topics outside of these areas may also be admitted on request but must be individually approved by the examination board. For such an exception it must be plausibly justified that the chosen topic is related to the curriculum of the master's degree programme in International Software Systems Science.		
Learning outcomes: Through the successful completion of the master's thesis the examinee <ul style="list-style-type: none"> • demonstrates that they are able to conduct independent research; • produce technical solutions to a research problem of substantial size, • arising and identified from the current state of the art and • critically evaluate the contributions made. on the basis of the specific knowledge acquired during their degree studies.		
prerequisites for the module: The master's thesis cannot be registered and thus confirmed by the examination board until at least 60 ECTS credit points have been successfully completed towards the degree.		
Recommended prior knowledge: none		Admission requirements: none
Frequency: every semester	Recommended semester: 4.	Minimal Duration of the Module: 1 Semester

Examination Coursework Assignment / Duration of Coursework: 6 months Description: The marks obtained from the written work is weighted 67% of the total grade for the master's thesis module.	
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Examination Colloquium Description: The examination includes a presentation (Kolloquium) of a duration between 20 and 60 minutes. The purpose of the presentation is for the student to defend their main results of the thesis. The thesis will be weighted with 67%, the presentation with 33%.	
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<p>The presentation will take place before or after the grading of the thesis, according to the student's preference.</p>	
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Module SWT-ASV-M Applied Software Verification <i>Applied Software Verification</i>		6 ECTS / 180 h
(since WS19/20) Person responsible for module: Prof. Dr. Gerald Lüttgen		
Contents: This module focuses on the increasingly important field of automated software verification, which aims at increasing the quality of today's complex computer systems. Students will be introduced to modern automated software verification and, in particular, to software model checking, and will be familiarised with a variety of important formal verification concepts, techniques and algorithms, as well as with state-of-the-art verification tools.		
Learning outcomes: On completion of this module, students will be able to thoroughly analyse software using modern software verification tools and understand the state-of-the-art techniques and algorithms that drive cutting-edge development environments offered by major software companies.		
Remark: The main language of instruction is English. The lectures and practicals may be delivered in German if all participating students are fluent in German. The total workload of 180 hrs. is split approximately as follows: <ul style="list-style-type: none"> • 30 hrs. attending lectures (Vorlesungen) • 30 hrs. attending practicals (Übungen) • 60 hrs. preparing and reviewing the lectures and practicals, including researching literature, studying material from additional sources and applying software tools • 30 hrs. working on the assignment (Hausarbeit) • 30 hrs. preparing for the colloquium (Kolloquium) 		
prerequisites for the module: none		
Recommended prior knowledge: Basic knowledge in algorithms and data structures, mathematical logic and theoretical computer science. Knowledge of the module "Foundations of Software Analysis" (SWT-FSA-B) - or equivalent - is desirable.		Admission requirements: none
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
1. Applied Software Verification Mode of Delivery: Lectures Lecturers: Prof. Dr. Gerald Lüttgen Language: English/German Frequency: every summer semester	2,00 Weekly Contact Hours
Contents: The lectures (Vorlesungen) will address the following topics in automated software verification: (i) state machines, assertions and algorithms for state	

<p>space exploration; (ii) temporal logics for specifying program properties; (iii) model checking using binary decision diagrams; (iv) SAT-based bounded model checking; (v) software model checking based on decision procedures; (vi) abstraction-based software model checking. In addition, several state-of-the-art software verification tools will be introduced.</p> <p>Literature:</p> <ul style="list-style-type: none"> • Baier, C., Katoen, J.-P. Principles of Model Checking. MIT Press, 2008. • Clarke, E., Grumberg, O., Kroening, D., Peled, D. and Veith, H. Model Checking. 3rd. ed. MIT Press, 2018. • Huth, M. and Ryan, M. Logic in Computer Science. 2nd ed. Cambridge University Press, 2004. • Kroening, D. and Strichman, O. Decision Procedures: An Algorithmic Point of View. Springer, 2008. • Loeckx, J. and Sieber, K. The Foundations of Program Verification. 2nd ed. Wiley, 1987. 	
<p>2. Applied Software Verification Mode of Delivery: Practicals Lecturers: Scientific Staff Praktische Informatik, insbesondere Softwaretechnik und Programmiersprachen Language: English/German Frequency: every summer semester</p> <hr/> <p>Contents: Students will practice the various theoretical and practical concepts taught in the lectures (Vorlesungen) by applying them to solve verification problems using several modern model-checking tools, and also by engaging in pen-and-paper exercises. Emphasis will be put on presenting and discussing the solutions to the exercises by and among the students, within the timetabled practicals (Übungen).</p> <hr/> <p>Literature: - see the corresponding lectures -</p>	<p>2,00 Weekly Contact Hours</p>

<p>Examination Coursework Assignment and Colloquium / Duration of Examination: 20 minutes Duration of Coursework: 3 weeks</p> <p>Description: Assignment (Hausarbeit) consisting of questions that practice, review and deepen the knowledge transferred in the lectures and practicals (Vorlesungen und Übungen). The assignment is set in English language, while answers may be provided in either English or German.</p> <p>Colloquium (Kolloquium) consisting of questions testing the knowledge transferred in the lectures and practicals (Vorlesungen und Übungen), on the basis of the submitted solutions to the assignment (Hausarbeit). The colloquium can be held electively in English or German language.</p>	
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Module SWT-CPS-M Cyber-Physical Systems <i>Cyber-Physical Systems</i>		6 ECTS / 180 h
(since WS20/21) Person responsible for module: Prof. Dr. Gerald Lüttgen		
<p>Contents:</p> <p>Cyber-physical systems are digital systems that physically control their environment in reaction to environmental changes. As such, the control software needs to consider in real-time both discrete and continuous behaviours in a hybrid fashion. Cyber-physical systems are becoming prevalent in our daily lives, e.g., in autonomous transportation, industrial robotics and bionics, where the reliability, correctness and quality of their software are of paramount importance.</p> <p>This module discusses the foundational concepts employed in the development of cyber-physical systems, in particular discrete, timed and hybrid automata for modelling, techniques for timing analysis and functional verification, and languages and paradigms for implementation and deployment.</p>		
<p>Learning outcomes:</p> <p>On completion of this module, students will be able to understand the context and concepts of cyber-physical systems and their development. In particular, students will be able to model, analyse, implement, deploy and verify simple cyber-physical systems using state-of-the-art techniques.</p>		
<p>Remark:</p> <p>The language of instruction is English.</p> <p>The total workload of 180 hrs. is split approximately as follows:</p> <ul style="list-style-type: none"> • 30 hrs. attending lectures (Vorlesungen) • 30 hrs. attending practicals (Übungen) • 90 hrs. preparing and reviewing the lectures and practicals, researching literature and studying material from additional sources • 30 hrs. preparing for the written exam (Klausur) 		
<p>prerequisites for the module:</p> <p>None</p>		
<p>Recommended prior knowledge:</p> <p>Basic knowledge in Theoretical Computer Science, such as gained, e.g., in the module "Machines and Languages" (GdI-GTI-B), and in mathematics, particularly in linear algebra, differentiation and integration. Knowledge gained in program semantics and verification, e.g., in the modules "Foundations of Software Analysis" (SWT-FSA-B) and "Applied Software Verification" (SWT-ASV-M), is beneficial but not necessary for following the module's content</p>		<p>Admission requirements:</p> <p>None</p>
<p>Frequency: every winter semester</p>	<p>Recommended semester:</p>	<p>Minimal Duration of the Module:</p> <p>1 Semester</p>
<p>Module Units</p>		
<p>1. Cyber-Physical Systems Mode of Delivery: Lectures Lecturers: Eugene Yip, Scientific Staff Praktische Informatik, insbesondere Softwaretechnik und Programmiersprachen</p>		<p>2,00 Weekly Contact Hours</p>

<p>Language: English Frequency: every winter semester</p> <hr/> <p>Learning outcome: – see the module's learning outcomes/competences (Lernziele/Kompetenzen) listed above –</p> <hr/> <p>Contents: Students are introduced to languages and paradigms for modelling and developing cyber-physical systems. The lectures first motivate cyber-physical systems and lay the foundation for formal modelling with discrete automata. Key semantic concepts, including the synchronous paradigm, are illustrated using the ForeC language. Next, discrete automata are enriched with time-dependent behaviour into timed automata. Techniques for verifying design properties via model checking are studied, and exemplified using the UPPAAL modelling and verification framework. To capture dynamical systems, timed automata are then extended with ordinary differential equations into hybrid automata, and the decidability of basic properties on hybrid automata is investigated. MATLAB Simulink/Stateflow, an industrial model-based development environment, is used for simulating hybrid systems and for highlighting realisation issues. Several topics on the deployment of automata as software components in a cyber-physical system are also addressed, namely compilation, scheduling disciplines and timing analysis. In particular, the Logical Execution Time (LET) programming paradigm is discussed as a means to execute automata together in a semantics-preserving manner.</p> <hr/> <p>Literature:</p> <ul style="list-style-type: none"> • Lee, E. A. and Seshia, S. A. Introduction to Embedded Systems: A Cyber-Physical Systems Approach, 2nd ed. MIT Press, 2017. • Alur, R. Principles of Cyber-Physical Systems. MIT Press, 2015. • Baier, C. and Katoen, J.-P. Principles of Model Checking. MIT Press, 2008. • Yip, E., Roop, P. S., Biglari-Abhari, M. and Girault, A. Programming and Timing Analysis of Parallel Programs on Multicores. In Application of Concurrency to System Design (ACSD), IEEE, 2013. • Kirsch, C. M. and Sokolova, A. The Logical Execution Time Paradigm. In Advances in Real-Time Systems. Springer, 2012. <p>Further literature will be announced at the beginning of the module.</p>	
<p>2. Cyber-Physical Systems Mode of Delivery: Practicals Lecturers: Scientific Staff Praktische Informatik, insbesondere Softwaretechnik und Programmiersprachen Language: English Frequency: every winter semester</p> <hr/> <p>Learning outcome: – see the module's learning outcomes/competences (Lernziele/Kompetenzen) listed above –</p> <hr/> <p>Contents:</p>	<p>2,00 Weekly Contact Hours</p>

The practicals (Übungen) deepen the concepts and techniques taught in the lectures (Vorlesungen).	
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Literature:

– see the corresponding lectures –

Examination

Written examination / Duration of Examination: 90 minutes

Description:

Written exam (Klausur) consisting of questions that relate to the contents of the lectures (Vorlesungen) and practicals (Übungen) of this module.

The exam is passed if at least 50% of the available points are reached.

Module SWT-PCC-M Principles of Compiler Construction		6 ECTS / 180 h
<i>Principles of Compiler Construction</i>		
(since WS20/21)		
Person responsible for module: Prof. Dr. Gerald Lüttgen		
Contents:		
The module teaches the theoretical and practical principles of compiler construction, from lexical analysis and parsing, to semantic analysis, to code generation and optimisation.		
Learning outcomes:		
On completion of this module, students will be familiar with all phases of a modern compiler – from lexical analysis and parsing, to semantic analysis and finally code generation and code optimisation – and will have a deep understanding of the workings of compilers. As a result, students will be able to use compilers more effectively and learn better debugging practices. Students will also be able to start building compilers on their own.		
Remark:		
The main language of instruction is English. The lectures and practicals may be delivered in German if all participating students are fluent in German.		
The total workload of 180 hrs. is split approximately as follows:		
<ul style="list-style-type: none"> • 30 hrs. attending lectures (Vorlesungen) • 30 hrs. reviewing the lectures, including researching and studying material from additional sources • 30 hrs. attending practicals (Übungen) • 30 hrs. preparing and reviewing the practicals, including researching and studying material from additional sources • 60 hrs. working on the assignment (Hausarbeit) and preparing for the colloquium (Kolloquium) 		
prerequisites for the module:		
none		
Recommended prior knowledge:		Admission requirements:
Basic knowledge in programming languages, in the theoretical foundations of Computer Science (especially in language theory and automata theory) and in algorithms and data structures.		none
Frequency: every summer semester	Recommended semester:	Minimal Duration of the Module:
		1 Semester

Module Units**1. Principles of Compiler Construction****Mode of Delivery:** Lectures**Lecturers:** Prof. Dr. Gerald Lüttgen**Language:** English/German**Frequency:** every summer semester**Contents:**

Students will be familiarised with a variety of theoretical and practical concepts, techniques and algorithms employed in compiler construction, which reach from language theory, to automata theory, and to data flow analysis. The lectures will

2,00 Weekly Contact Hours

focus on the following aspects of compiler construction: lexical analysis, parsing, abstract syntax, semantic analysis, code generation and code optimisation.

Literature:

- Louden, K. C. Compiler Construction: Principles and Practice. Course Technology, 1997.
- Aho, A. V., Lam, M. S., Sethi, R. and Ullman, J. D. Compilers: Principles, Techniques, and Tools, 2nd ed. Pearson, 2007.
- Fischer, C. N., Cytron, R. K. and LeBlanc Jr., R. J. Crafting a Compiler. Pearson, 2010.
- Muchnick, S. S. Advanced Compiler Design and Implementation, Morgan Kaufmann, 1997.

2. Principles of Compiler Construction

Mode of Delivery: Practicals

Lecturers: Prof. Dr. Gerald Lüttgen, Scientific Staff Praktische Informatik, insbesondere Softwaretechnik und Programmiersprachen

Language: English/German

Frequency: every summer semester

Contents:

Students will practice the theoretical concepts taught in the lectures by applying them to a variety of exercises, so that they can appreciate the diverse range of foundations that make modern programming languages possible. The exercises will largely be pen-and-paper exercises but may also involve some work using computers. Emphasis will be put on presenting and discussing the solutions to the exercises by and among the students, within the timetabled practicals (Übungen). Students can gain further practical experience in compiler construction by attending one of the modules "Masterprojekt Softwaretechnik und Programmiersprachen" (SWT-PR1-M) or "Masters Project in Software Systems Science" (SWT-PR2-M).

Literature:

- see the corresponding lectures -

Examination

Coursework Assignment and Colloquium / Duration of Examination: 20 minutes

Duration of Coursework: 3 weeks

Description:

Assignment (Hausarbeit) consisting of questions practicing, reviewing and deepening the knowledge transferred in the lectures (Vorlesungen) and practicals (Übungen). The examination is set in English language, while answers may be provided in either English or German.

Colloquium (Kolloquium) consisting of questions testing the knowledge transferred in the lectures (Vorlesungen) and practicals (Übungen), on the basis of the submitted solutions to the assignment (Hausarbeit). The colloquium can be held electively in English or German language.

2,00 Weekly Contact Hours

Module SWT-PR2-M SWT Masters Project in Software Systems Science <i>SWT Masters Project in Software Systems Science</i>		9 ECTS / 270 h
(since WS19/20) Person responsible for module: Prof. Dr. Gerald Lüttgen		
Contents: Attention: The module SWT-PR2-M cannot take place in winter semester 2019/20! Topics in Software Systems Science are carried out individually or in teams of students, from conception, via theoretical and/or practical realization, to evaluation. In particular, the project concerns the development of sound concepts pertaining to the task to be addressed under the given project constraints. This requires studying academic literature and relevant technologies and approaches on the project's topic. An example of a project task would be the conceptual development, the prototypic implementation, and the case-study-driven evaluation of tools for software verification, which requires the prior attendance of the module "Applied Software Verification" (SWT-ASV-M), or equivalent knowledge. Another example would be designing and implementing a compiler of a small programming language in either an imperative, object-oriented or functional language, which requires the prior attendance of the module "Principles of Compiler Construction" (SWT-PCC-M), or equivalent knowledge.		
Learning outcomes: Students will deepen their knowledge regarding the conceptual problems that arise when carrying out scientific projects related to Software Systems Science, and regarding approaches to possible solutions. Students will also gain important experience in carrying out such projects, from project planning, to the abstract and concrete design, to the realization, to the documentation of results in a scientific project report.		
Remark: The main language of instruction is English. The module may be delivered in German if all participating students are fluent in German. A regular participation in the project meetings is necessary. The total workload of 270 hrs. is split approximately as follows: <ul style="list-style-type: none"> • 10 hrs. participating in introductions to and tutorials on methods, software tools, and giving presentations on the project status • 20 hrs. completing the exercises for bonus points • 195 hrs. researching and familiarization with the project topic and conducting the project work • 45 hrs. compiling a project report (Assignment/Hausarbeit) and preparation of the Colloquium (Kolloquium). The project report can be written/composed in either English or German.		
prerequisites for the module: none		
Recommended prior knowledge: Basic knowledge in software engineering and programming languages, knowledge in the subject matter of the project topic.		Admission requirements: none
Frequency: every semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
<p>SWT Masters Project in Software Systems Science</p> <p>Mode of Delivery: Practicals</p> <p>Lecturers: Prof. Dr. Gerald Lüttgen</p> <p>Language: English/German</p> <p>Frequency: every semester</p> <hr/> <p>Learning outcome:</p> <p>To be announced at the beginning of the project.</p> <hr/> <p>Contents:</p> <p>Conduct of the project, accompanied by tutorials and regular project meetings.</p> <hr/> <p>Literature:</p> <p>To be announced at the beginning of the project.</p>	<p>6,00 Weekly Contact Hours</p>

<p>Examination</p> <p>Coursework Assignment and Colloquium / Duration of Examination: 30 minutes</p> <p>Duration of Coursework: 12 weeks</p> <p>prerequisites for module examination:</p> <p>Regular participation in the practicals.</p> <p>Description:</p> <p>Production of a written report on the software project carried out (Assignment/Hausarbeit). Discussion of this project report and of the developed artefacts in the context of the wider project topic (Colloquium/Kolloquium).</p>	
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Module SWT-SEM-M Seminar in Software Engineering and Programming Languages (Master)		3 ECTS / 90 h
<i>Seminar Software Engineering and Programming Languages (Master)</i>		
(since WS17/18)		
Person responsible for module: Prof. Dr. Gerald Lüttgen		
Contents: Current topics in software engineering and programming languages. This may comprise the full spectrum of research topics in these fields, from the analysis, comparison and evaluation of current software technologies and tools, to the discussion and evaluation of novel research proposals.		
Learning outcomes: Students will compile and acquire current topics in software engineering and programming languages by independently carrying out and documenting a literature survey, and by preparing and delivering a coherent, comprehensible presentation to their peers. Students will also be able to scientifically discuss topics in software engineering and programming languages with their peers.		
Remark: The main language of instruction is English. The seminar may be delivered in German if all participating students are fluent in German. Regular participation in the presentations is required. The total workload of 90 hrs. is split approximately as follows: <ul style="list-style-type: none"> • 20 hrs. consultations and presentations (Referate), including discussions • 25 hrs. literature research and familiarization and evaluation of literature • 45 hrs. working on the assignment (Hausarbeit) and preparation for the presentation (Referat) 		
prerequisites for the module: none		
Recommended prior knowledge: Basic knowledge in software engineering, in programming languages and in the subject matter of the seminar. Additionally, basic knowledge of scientific methods is expected.		Admission requirements: none
Frequency: every semester	Recommended semester:	Minimal Duration of the Module: 1 Semester

Module Units	
Software Engineering and Programming Languages (Master) Mode of Delivery: Seminar Lecturers: Prof. Dr. Gerald Lüttgen, Scientific Staff Praktische Informatik, insbesondere Softwaretechnik und Programmiersprachen Language: English/German Frequency: every semester	2,00 Weekly Contact Hours
Contents: Various current topics in software engineering and programming languages, which complement and/or extend the technical and methodological aspects of the degree programme's modules related to these fields.	
Literature: Will be allocated according to the topics to be discussed.	

Examination

Coursework Assignment with presentation / Duration of Examination: 40 minutes

Duration of Coursework: 8 weeks

prerequisites for module examination:

Regular participation in the seminar.

Description:

Assignment (Hausarbeit) consisting of a written report on the topic assigned to the student.

Presentation (Referat) on the topic assigned to the student, including a discussion.

Module Handbook Summary

ID	Module	Semester	ECTS	Weekly Contact Hours	Examination
Software Systems Science for students starting before WS 19/20					
In module groups A1 and A2, modules totalling 48 ECTS points are to be completed in accordance with the minimum and maximum limits applicable to the module groups.					
DSG-DSAM-M	Distributed Systems Architectures and Middleware	every winter semester	6	2 Lectures 2 Practicals	Coursework Assignment and Colloquium 3 months 15 minutes
DSG-DistrSys-M	Distributed Systems	every summer semester(2020)	6	2 Lectures 2 Practicals	Coursework Assignment and Colloquium 3 months 15 minutes
DSG-SOA-M	Service-Oriented Architecture and Web Services	every summer semester	6	2 Lectures 2 Practicals	Coursework Assignment and Colloquium 3 months 15 minutes
DSG-SRDS-M	Selected Readings in Distributed Systems	every semester	3	2 Lectures and Seminar	Coursework Assignment and Colloquium 4 months 20 minutes
Gdl-AFP-M	Advanced Functional Programming	every summer semester	6	2 Lectures 2 Practicals	Written examination 90 minutes Oral examination 30 minutes
Gdl-FP-M	Functional Programming	every winter semester	6	2 Lectures 2 Practicals	Written examination 90 minutes
KTR-GIK-M	Foundations of Internet Communication	every summer semester(on	6	4 Lectures and Practicals	Coursework Assignment and Colloquium 4 months 30 minutes

Module Handbook Summary

		demand also WS)			
KTR-MAKV-M	Modeling and Analysis of Communication Networks and Distributed Systems	every summer semester	6	4 Lectures and Practicals	Oral examination 30 minutes
KTR-MMK-M	Multimedia Communication in High Speed Networks	every summer semester	6	4 Lectures and Practicals	Oral examination 30 minutes
KTR-Mobi-M	Mobile Communication	every winter semester	6	4 Lectures and Practicals	Oral examination 30 minutes
MOBI-ADM-M	Advanced Data Management	every summer semester(1)	6	2 Lectures 2 Practicals	Written examination 60 minutes
MOBI-DSC-M	Data Streams and Complex Event Processing	every winter semester(1)	6	2 Lectures 2 Practicals	Oral examination 15 minutes Written examination 60 minutes
PSI-AdvaSP-M	Advanced Security and Privacy	every summer semester(1)	6	2 Lectures 2 Practicals	Written examination 90 minutes
SWT-ASV-M	Applied Software Verification	every summer semester	6	2 Lectures 2 Practicals	Coursework Assignment and Colloquium 3 weeks 20 minutes
SWT-CPS-M	Cyber-Physical Systems	every winter semester(1)	6	2 Lectures 2 Practicals	Written examination 90 minutes
SWT-PCC-M	Principles of Compiler Construction	every summer semester	6	2 Lectures 2 Practicals	Coursework Assignment and Colloquium 3 weeks 20 minutes

Module Handbook Summary

ID	Module	Semester	ECTS	Weekly Contact Hours	Examination
A1 Software Systems Science for students starting from WS 1920 onwards			30 - 48		
In module groups A1 and A2, modules totalling 48 ECTS credits must be completed in accordance with the minimum and maximum limits applicable to the module groups.					
Teilmodulgruppe: elective modules			0 - 18		
DSG-DistrSys-M	Distributed Systems	every summer semester(2020)	6	2 Lectures 2 Practicals	Coursework Assignment and Colloquium 3 months 15 minutes
DSG-SOA-M	Service-Oriented Architecture and Web Services	every summer semester	6	2 Lectures 2 Practicals	Coursework Assignment and Colloquium 3 months 15 minutes
DSG-SRDS-M	Selected Readings in Distributed Systems	every semester	3	2 Lectures and Seminar	Coursework Assignment and Colloquium 4 months 20 minutes
Gdl-AFP-M	Advanced Functional Programming	every summer semester	6	2 Lectures 2 Practicals	Written examination 90 minutes Oral examination 30 minutes
Gdl-FP-M	Functional Programming	every winter semester	6	2 Lectures 2 Practicals	Written examination 90 minutes
KTR-MAKV-M	Modeling and Analysis of Communication Networks and Distributed Systems	every summer semester	6	4 Lectures and Practicals	Oral examination 30 minutes
KTR-MMK-M	Multimedia Communication in High Speed Networks	every summer semester	6	4 Lectures and Practicals	Oral examination 30 minutes
KTR-Mobi-M	Mobile Communication		6	4 Lectures and Practicals	Oral examination

Module Handbook Summary

		every winter semester			30 minutes
MOBI-ADM-M	Advanced Data Management	every summer semester(1)	6	2 Lectures 2 Practicals	Written examination 60 minutes
SWT-ASV-M	Applied Software Verification	every summer semester	6	2 Lectures 2 Practicals	Coursework Assignment and Colloquium 3 weeks 20 minutes
SWT-CPS-M	Cyber-Physical Systems	every winter semester(1)	6	2 Lectures 2 Practicals	Written examination 90 minutes
Teilmodulgruppe: compulsory part			30		
DSG-DSAM-M	Distributed Systems Architectures and Middleware	every winter semester	6	2 Lectures 2 Practicals	Coursework Assignment and Colloquium 3 months 15 minutes
KTR-GIK-M	Foundations of Internet Communication	every summer semester(on demand also WS)	6	4 Lectures and Practicals	Coursework Assignment and Colloquium 4 months 30 minutes
MOBI-DSC-M	Data Streams and Complex Event Processing	every winter semester(1)	6	2 Lectures 2 Practicals	Oral examination 15 minutes Written examination 60 minutes
PSI-AdvaSP-M	Advanced Security and Privacy	every summer semester(1)	6	2 Lectures 2 Practicals	Written examination 90 minutes
SWT-PCC-M	Principles of Compiler Construction		6	2 Lectures 2 Practicals	Coursework Assignment and Colloquium

Module Handbook Summary

every
summer
semester

3 weeks
20 minutes

Module Handbook Summary

ID	Module	Semester	ECTS	Weekly Contact Hours	Examination
A2 Domain-specific Software Systems Science			0 - 18		
	In module groups A1 and A2, modules totalling 48 ECTS points are to be completed in accordance with the minimum and maximum limits applicable to the module groups.				
EESYS-DAE-M	Data Analytics in Energy Informatics	every winter semester	6	2 Lectures 2 Practicals	Written examination 90 minutes
EESYS-ES-M	Energy Efficient Systems	every summer semester	6	2 Lectures 2 Practicals	Written examination 90 minutes
Gdl-CSNL-M	Computational Semantics of Natural Language	every summer semester(1)	6	4	Portfolio
HCI-MCI-M	Human-Computer Interaction	every summer semester	6	2 Lectures 2 Practicals	Oral examination 30 minutes Written examination 90 minutes
HCI-US-B	Ubiquitous Systems	every winter semester	6	2 Lectures 2 Practicals	90 minutes Oral examination 30 minutes
KogSys-ML-M	Machine Learning	every winter semester	6	2 Lectures 2 Practicals	Written examination 90 minutes
SME-STE-M	Introduction to Knowledge Representation: Space, Time, Events	every winter semester	6	2 Lectures 2 Practicals	Oral examination 20 minutes
SNA-OSN-M	Project Online Social Networks	every winter semester	6	4 Practicals	Coursework Assignment and Colloquium 4 months 30 minutes

Module Handbook Summary

ID	Module	Semester	ECTS	Weekly Contact Hours	Examination
	A3 Seminar and Project		12		
	Teilmodulgruppe: Elective Unit A3WP1: Seminar		3		
DSG-Sem-M	Master Seminar in Distributed Systems	every semester	3	2 Key competence	Coursework Assignment with presentation 4 months 30 minutes
Gdl-Sem-M	Master's Seminar Theoretical Computer Science	winter or summer semester, on demand	3	2 Seminar	Coursework Assignment with presentation 4 months 30 minutes
HCI-Prop-M	Propaedeutic: Human-Computer-Interaction	every winter semester(1)	3	2 Seminar	Coursework Assignment with presentation 4 months 30 minutes
HCI-Sem-HCC-M	Master-Seminar Human-Centred Computing	every summer semester	3	2 Seminar	Coursework Assignment with presentation 4 months 30 minutes
HCI-Sem-M	Master-Seminar Human-Computer Interaction	every winter semester	3	2 Seminar	Coursework Assignment with presentation 4 months 30 minutes
KTR-Sem-M	Master Seminar Communication Systems and Computer Networks	winter or summer semester, on demand(Regelturnus: WS)	3	2 Advanced seminar	Coursework Assignment with presentation 4 months 40 minutes
KogSys-Sem-M2	Reading Club Cognitive Systems		3	2 Seminar, Key competence	Coursework Assignment with presentation

Module Handbook Summary

		every summer semester			4 months 30 minutes
MOBI-SEM-M	Master-Seminar Mobile Software Systems	every winter semester(1)	3	2 Seminar	Coursework Assignment with presentation
PSI-Sem-M	Seminar Research Topics in Security and Privacy	every winter semester(1)	3	2 Seminar	Coursework Assignment with presentation 3 months 30 minutes
SWT-SEM-M	Seminar in Software Engineering and Programming Languages (Master)	every semester	3	2 Seminar	Coursework Assignment with presentation 8 weeks 40 minutes
Teilmodulgruppe: Project			9		
MOBI-PRS-M	Master Project Mobile Software Systems (SoSySc)	every summer semester(1)	9	6 Practicals	Coursework Assignment and Colloquium
DSG-Project-M	Master Project Distributed Systems	every semester	9	6 Practicals	Coursework Assignment and Colloquium 3 months 10 minutes
SWT-PR2-M	SWT Masters Project in Software Systems Science	every semester	9	6 Practicals	Coursework Assignment and Colloquium 12 weeks 30 minutes
KTR-SSSProj-M	KTR Master Project Software Systems Science	every semester(Beginn WS)	9	6	Coursework Assignment and Colloquium 4 months 30 minutes

Module Handbook Summary

PSI-ProjectCAD-M Project Complex Attacks and Defenses	every semester(1)	9	6 Practicals	Coursework Assignment and Colloquium 3 months 30 minutes
PSI-ProjectSP-M Project Security and Privacy	every semester(1)	9	6 Practicals	Coursework Assignment and Colloquium 3 months 30 minutes

Module Handbook Summary

ID	Module	Semester	ECTS	Weekly Contact Hours	Examination
	A4: Masters Thesis		30		
SSS-Thesis-M	Master's Thesis in Software Systems Science	every semester	30		Coursework Assignment 6 months Colloquium

Module Handbook Summary

ID	Module	Semester	ECTS	Weekly Contact Hours	Examination
	A5 International Experience		30		
	<p>According to the examination regulations (StuFPO) Appendix 1, students have four options regarding the Module Group A5, <i>International Experience</i>, which may also be combined:</p> <p>(1) to study modules of software systems science at a university abroad for at least one semester or</p> <p>(2) to accomplish a traineeship in an international context, preferentially abroad, that covers topics of the occupational field of software systems science with a volume of at least 360 working hours (12 ECTS credits).</p> <p>(3) to accomplish <i>further</i> modules of module groups A1 and A2 (Examination Regulations, App. 1)</p> <p>(4) to accomplish up to 18 ECTS credits in modules of foreign languages (neither English nor native language).</p>				
	Teilmodulgruppe: Guided graduate study abroad		0 - 30		
	<p>Regarding the study of software systems science modules at a university abroad, courses with a workload equivalent to 30 ECTS credits can be accomplished.</p> <p>The courses that are selected at a foreign university have to be approved by learning agreements. For own planning security reasons, learning agreements have to be signed by those Professors at University of Bamberg responsible for the chosen subject, as well as the head of the Examination Board, before the graduate study abroad is initiated.</p>				
	Teilmodulgruppe: Internship in an International context		0 - 12		
	<p>Regarding the elective area 5b, <i>Internship in an international context</i>, with an equivalent workload of 12 ECTS credits, a foreign or internationally acting domestic company (or research institute) may be selected.</p> <p>It has to offer a specific internship related to relevant topics of software systems science. The documentation of the internship requires the delivery of the following items to the degree programme representative:</p> <ul style="list-style-type: none"> • written report of 4 pages at least, reporting on the tasks and achievements, and • a certificate issued by the hosting institution or the organizational unit that has realized the internship. 				
SSS-PraktIntKon- M	Internship in an International Context	every semester(1)	12		Written Report on Practical Training
	Teilmodulgruppe: Foreign languages		0 - 18		
	<p>In the elective area 5c, <i>Foreign languages</i>, modules comprising up to 18 ECTS credits can be taken from the range offered by the University's Language Centre. Excluded are modules of the English language and modules of the language in which the university entrance qualification was obtained.</p>				

Module Handbook Summary

Details, in particular the modules available for selection and the respective Module examinations are described (in German) in the *Modulhandbuch des Sprachenzentrums der Otto-Friedrich-Universität Bamberg*.

Module Group: further modules from module groups A1 and/ or A2 0 - 30

Additional, not previously completed modules from A1 or A2 module groups' required elective options in accordance with the Examination Regulations, Appendix 1.